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~~Phase III Proposal~~

(6) Supersonic Transport Development Program

Phase III Proposal.

BOEING MODEL 2707.

VOLUME II-1.

SYSTEM ENGINEERING REPORT

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1.0 INTRODUCTION

The System Engineering Report is one of a series of documents under Volume II, Technical/Airplane, called for by the FAA Request for Proposal for Phase III of the Supersonic Transport Development Program. The System Engineering Report is bound into two documents: System Engineering Report V2-B2707-1, and Mockup Plan, V2-B2707-2. This document presents the Boeing Supersonic Transport system concept and the design integration aspects that demonstrate the optimum overall approach to the SST design Operational integration of the System Concept is discussed in V4-B2707-1 and deals with integration of the B-2707 System Concept into the world-wide air transportation system.

The air transportation system is comprised of the following basic elements; (Fig. 1-1):

- Airlines;
- Airports;
- Governmental facilities and agencies;
- Passengers and cargo; and
- Airplane.

Contained herein are the influences of these elements upon the design of the Boeing Model 2707 and the attendant trade studies associated with the integration of the airplane with the requirements of these other elements of the transportation system.

The techniques and activities used in ensuring comprehensive investigation of the design requirements necessary to explore all facets of this integration program included:

a. A continuous program of airline contact through individual airline visits to the Boeing facilities and trips to their bases, formalized meetings with the Airline SST Committee and its specialist teams, specification reviews, training program discussions, operational route analyses, and economic studies. Further airline operational and maintenance information available from the company's extensive experience of current subsonic jet transportation operations is also under continuing review for application to B-2707 design considerations.

b. Airport requirements have been obtained by direct field contact with the 15 major U.S. international airports and by questionnaire from the major non-U.S. airports through which the B-2707 is expected to operate.

c. Governmental regulations concerning air traffic control, air worthiness requirements, operating regulations, and other associated aviation operational and safety constraints have been diligently reviewed for assessment of influence on, or establishment of, design requirements.

d. Market surveys of air transportation demand in passenger and cargo categories throughout the world are under continuing review. Other elements sensitive to public reaction are noise adjacent to airports and sonic boom which are subjects of specific study programs in addition to influencing airplane design.

e. The influence of the manufacturer of the airplane on its design is inherent in its relationship and demand special disciplines to ensure proper emphasis to produce an airplane at economical cost.

A tool employed to ensure completness of the engineering of the airplane is the functional-analysis technique of System Engineering. Each activity in which the airplane is involved, whether it is related to the operation of the airplane itself or related to the functioning with other elements of the air transportation system, have been examined.

Studies and analyses to substantiate the Boeing SST system concept, including parametric design studies and analyses, are presented in Sec. 2.0, System Concept.

Detail description and drawings of the airplane and its design features are presented in Sec. 3.0, Airplane Description.

Design integration, including trade-off studies to ensure capability of the major airplane components, and performance optimization are included in Sec. 4.0, Design Integration.

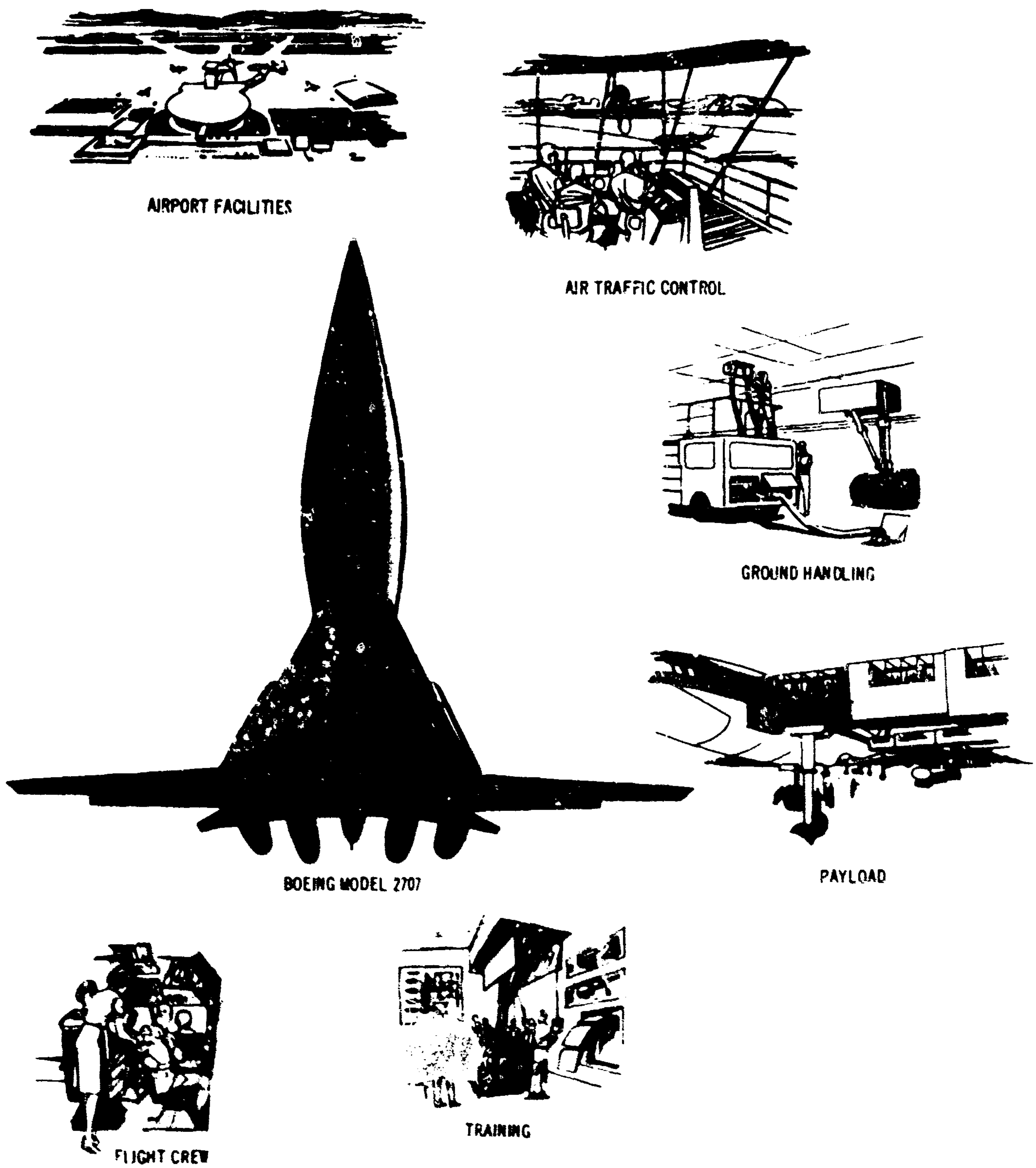

Figure 1-1. Elements of the SST Program

CONTENTS

2.0 SYSTEM CONCEPT

Boeing studies of air transport traffic potential and supersonic flight technology have evolved an SST system concept that offers superior air transportation characteristics in terms of safety, performance, and economics. Within the constraints of airport compatibility, airline operating requirements, noise, sonic boom and direct operating cost objectives, the Boeing SST system concept is an airplane that when integrated with its operational environment can accomplish the following:

a. Meets or exceeds the safety, comfort, and service requirements for the airline travelers in the time period subsequent to 1973.

b. Safety in the terminal area by means of low-approach and landing speeds comparable to current subsonic jet transports.

c. Handling qualities which will enable safe operation by pilots with average skill and work load capabilities.

d. Safe and efficient supersonic operation at a Mach number of 2.7.

e. Safe operation in the wordwide air traffic control environment including all-weather capability.

f. Normal transition training for flight and ground crews.

g. Competitive operating cost and return on investment by means of superior payload-range capabilities.

h. Economical maintenance and service by ground crews with skill levels equivalent to those being utilized in worldwide airline operations.

i. Is capable of subsonic and supersonic trip segments without a range penalty.

j. Can utilize essentially all the servicing and maintenance ground equipment expected to be in each airline inventory in the 1973 time period within turnaround and through flight-time requirements.

k. Dispatch and inflight reliability no less than subsonic jet transports.

The key to the success of the Boeing concept lies in the integration of these characteristics into a coherent and balanced system. Certain design features have evolved that are instrumental in this successful integration and include the following:

- Variable sweep wing
- Large payload capacity
- 4-post main landing gear
- Individual pod-mounted engines

The Boeing Model 2707 system concept embodying these features is illustrated in Fig. 2-1.

Specific performance and operating characteristics are shown in Table 2-A.

2.1 CRUISE SPEED SELECTION

Airplane designs with delta wings, arrow wings, and variable-sweep arrow wings have been studied at design Mach numbers from 1.2 to 3.5. It was apparent early in the studies that the speed range from Mach 1.2 to 2.2 would be of little interest because a competing airplane at higher speeds would force the slower airplane to early obsolescence; and cruise capabilities up to at least Mach 2.2 were economically achievable within current technological state of the art. Also, one of the important conclusions of the NASA-SCAT studies was that the operating economy of an aluminum airplane which would be restricted to speeds below Mach 2.2 was inferior to that of an airplane capable of higher cruise speeds. Concentration was therefore at speeds of Mach 2.2 and above with most of the work in the range from Mach 2.5 to Mach 3.2.

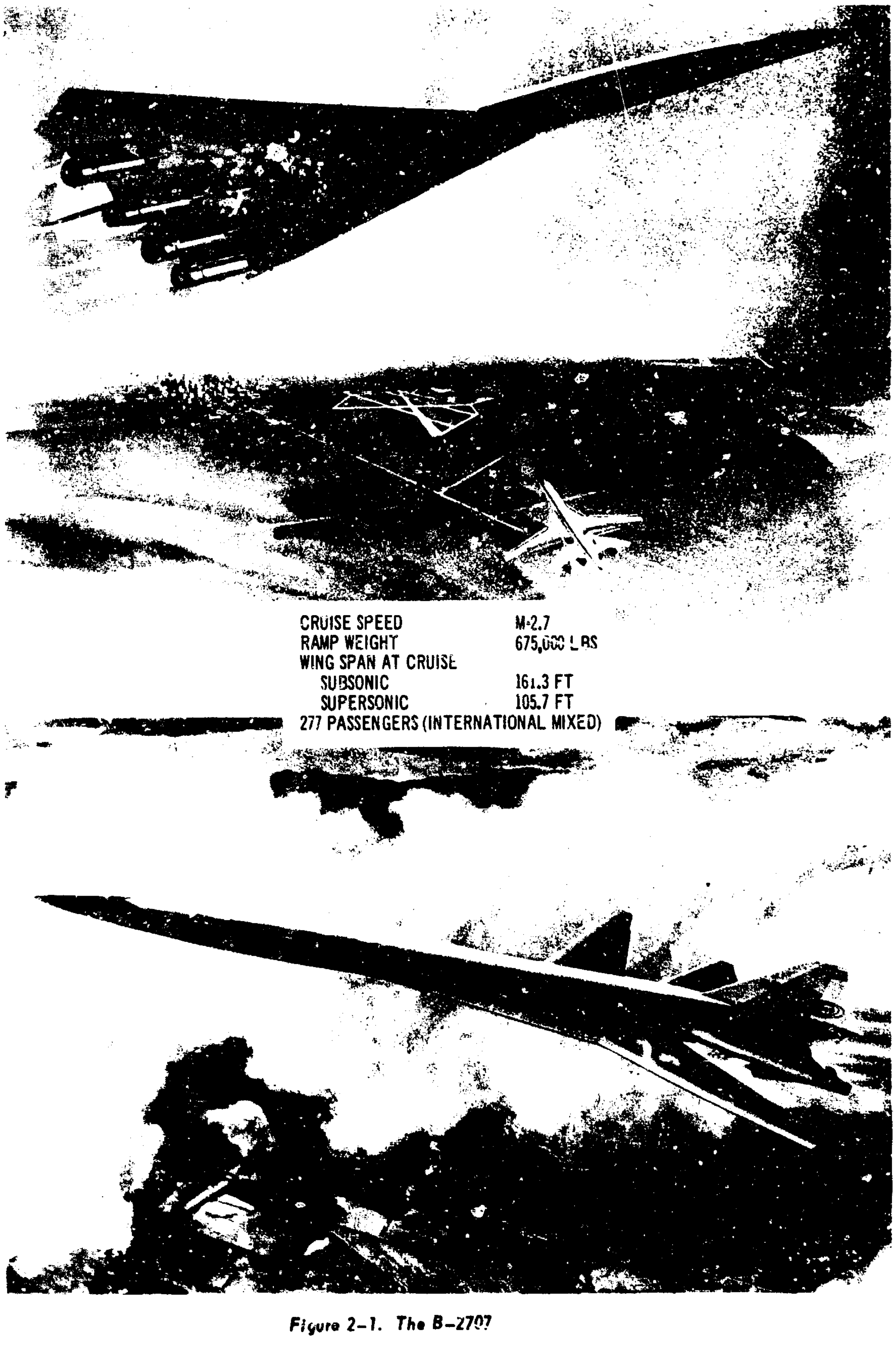

Figure 2-1. The B-2707

Table 2-A. Performance and Operating Characteristics

		B-2707	FAA OBJECTIVE
Maximum Taxi Weight, lb		675,000	
Nominal Payload, lb		50,000	
Range, st mi		4,380	4,000
Allowable Payload, lb		75,000	
Sonic Boom Overpressure, psf	Climb Max Range	2.5	2.5
	FAR Field Length, ft	7,000	
	Flap Setting, degrees	20°/40°	
Sea Level	Power Setting	Max Aug	
Std Day	Airport Noise, PNdb	121	116
	Community Noise, PNdb	100	105
	Liftoff Speed, kt	169	
Std +15°C	FAR Field Length, ft	8,300	10,500
Normal Landing Weight, lb		384,500	
Approach: Body Attitude = 6.8°	Speed, kt	144	
	Noise, PNdb (Const. V_{APP})	111	109
	Flap Setting, degrees	20°/40°	
Landing: Sea Level	FAR Field Length, ft		
	Dry Runway	6,900	
	Operational-Wet Runway, ft	7,000	8,000

Propulsive efficiency increases slowly with an increase in Mach number. Airplane range factor, which is the product of speed and aerodynamic efficiency divided by the engine specific fuel consumption, generally increases with Mach number as shown in Fig. 2-2.

The stagnation temperature (and hence all other temperatures, such as boundary-layer equilibrium temperature) increases as a function of the square of the Mach number. System weights, insulation, and air conditioning, increase in proportion to the temperature. The cost of these higher temperature environment systems also increases as a function of the design speed. The result of the increase in system, engine and structural weight for an increase in design Mach number is an increase in operating empty weight (OEW) as shown in Fig. 2-2. The OEW given is for a constant range of 4,000 st mi, a payload of 50,000 lbs and a sonic boom overpressure of 2.5 lbs/sq ft.

Solution of the Brequet range equation, range = $L/D \times V/SFC \times \ln W_1/W_2$ produces the variation in block and reserve fuel allowance (Fig. 2-2). Ramp gross weight and block time are shown in Fig. 2-3. Performance factors alone as represented by minimum ramp gross weight and block fuel would favor a choice of design Mach number of about 3.0.

Boeing has estimated parametrically the total airframe price (Fig. 2-4) as a function of Mach number based upon information from equipment suppliers and internal sources. Unit price is based upon the FAA economic ground rules for Phase II-C.

The engine manufacturers have supplied parametric variations of bare engine weight and price as a function of design speed. The data shown in Fig. 2-5 are the result of applying the engine manufacturer's price and weight data to the

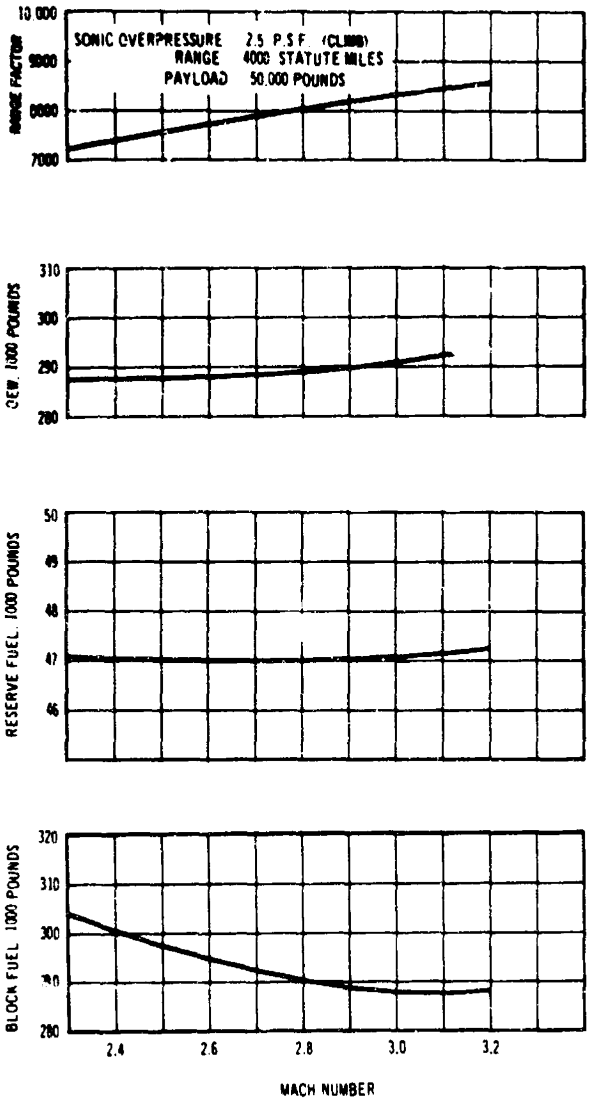

Figure 2-2. Performance Parameters

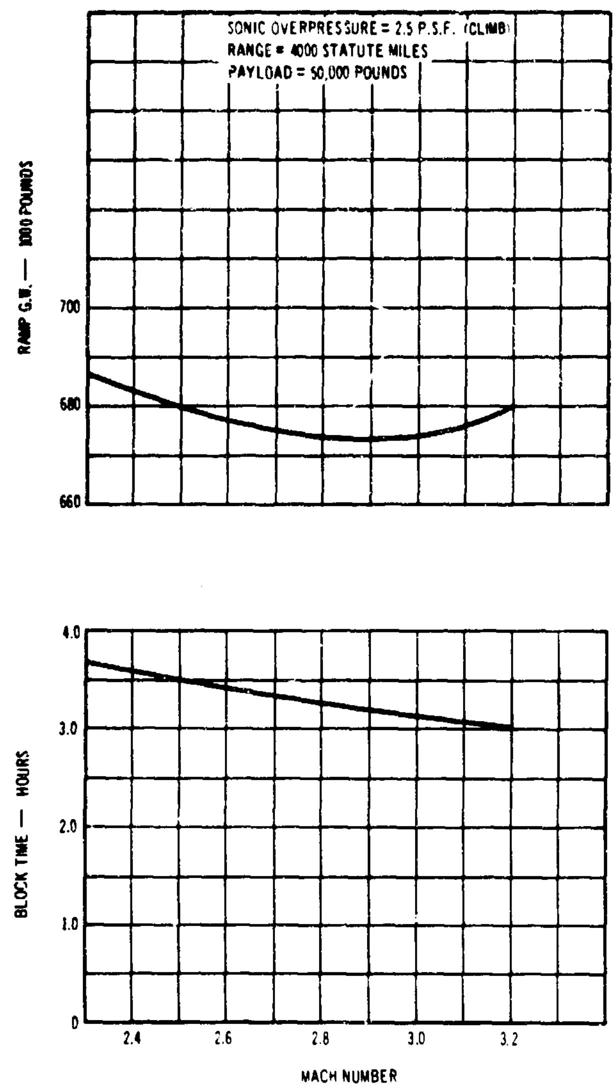

Figure 2-3. Ramp Gross Weight and Block Time

engine sizes which correspond to the ramp gross weights shown in Fig. 2-3. The major contribution to price is that of using higher temperature turbine type alloys as the engine temperatures increase. The engine price is also influenced by an increase in developmental facilities costs to achieve adequate high Mach number environment.

Aviation kerosene (Jet A) has good thermal stability up to temperatures of about 300° F to 325° F. For Mach numbers up to approximately 3.0, insulation in the fuel is supplied to the engines below the critical stability temperature. When the speed increases above Mach 3.0, the insulation required to hold the kerosene temperature becomes disproportionately large. It has been suggested that Jet A fuel could be allowed to increase to 350°F. However, this would involve additional cost because 30 to 70 percent of the nation's refineries cannot supply Jet A with this kind of thermal stability.

Fuel inerting will be required for design cruise speeds in excess of Mach 2.8. The cost and weight of the inerting system is not large, but inerting does require that the fuel be handled in a special manner. The variation of fuel costs including special handling and with increased thermal stability is shown in Fig. 2-6.

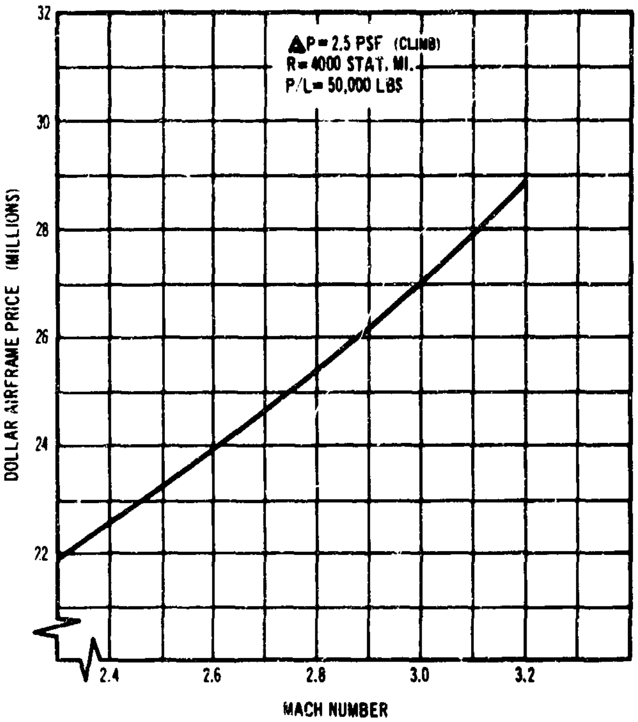

Figure 2-4. Airframe Price

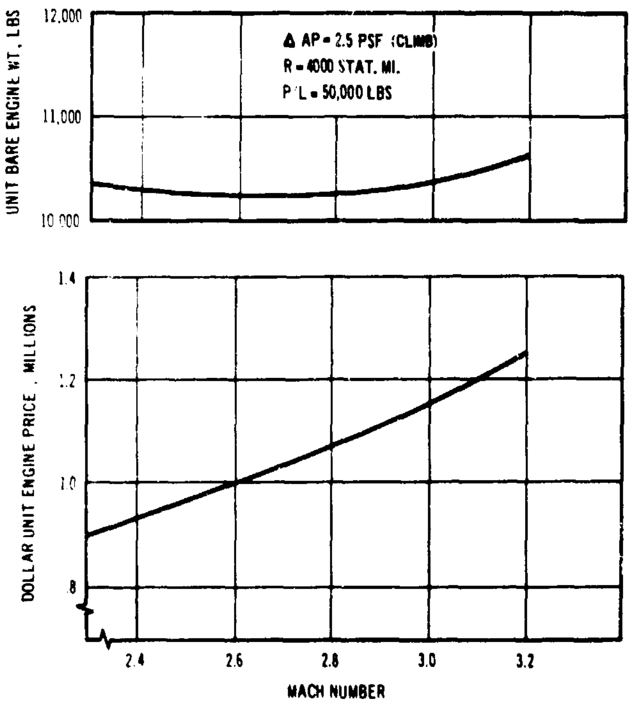

Figure 2-5. Engine Weight and Price

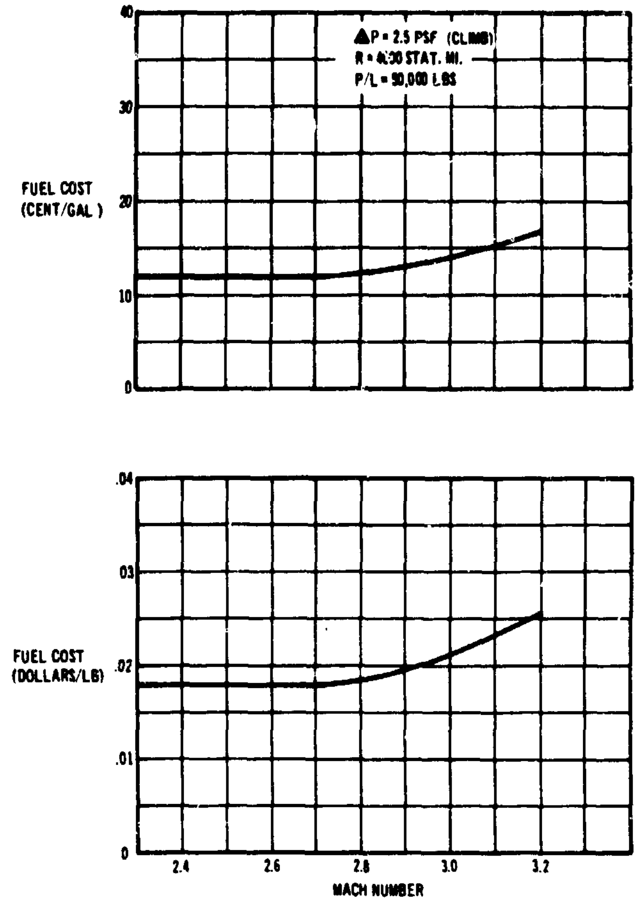

Figure 2-6. Fuel Price

The effect of speed on supersonic transport utilization has been studied, and several airlines have simulated SST airplanes on their routes. Fig. 2-7 shows the utilization rates as a function of speed. The rates are an average of Boeing and airline utilization computations. The reduced utilization rates at the higher speeds are the result of schedule curfew limits, off-design operation, and the proportionately larger influence of ground time and fixed air maneuver times. The results of computing the costs based on the foregoing inputs are shown in Figs. 2-8 and 2-9.

Based on the data presented, a Mach number of 2.7 has been selected as the design cruise speed. A cruise Mach number of 2.7 represents a high level of productivity without an increase in DOC. It is also a high enough speed to avoid the possibility of early obsolence without incurring excessive development risk. The B-2707 aerodynamic design, structure, and engines are fully

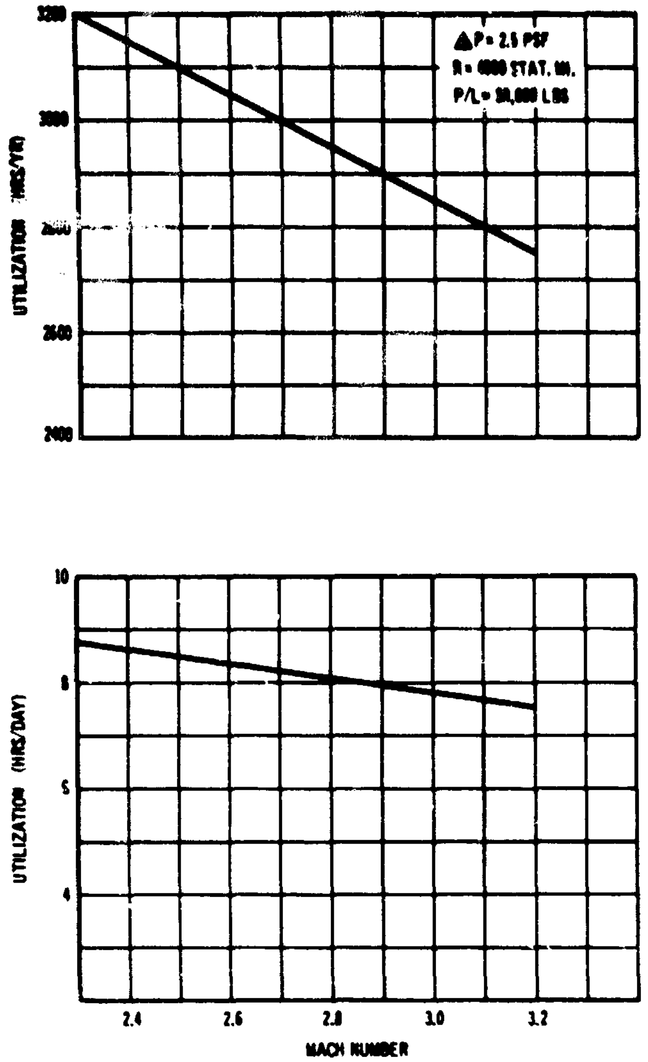

Figure 2-7. Utilization

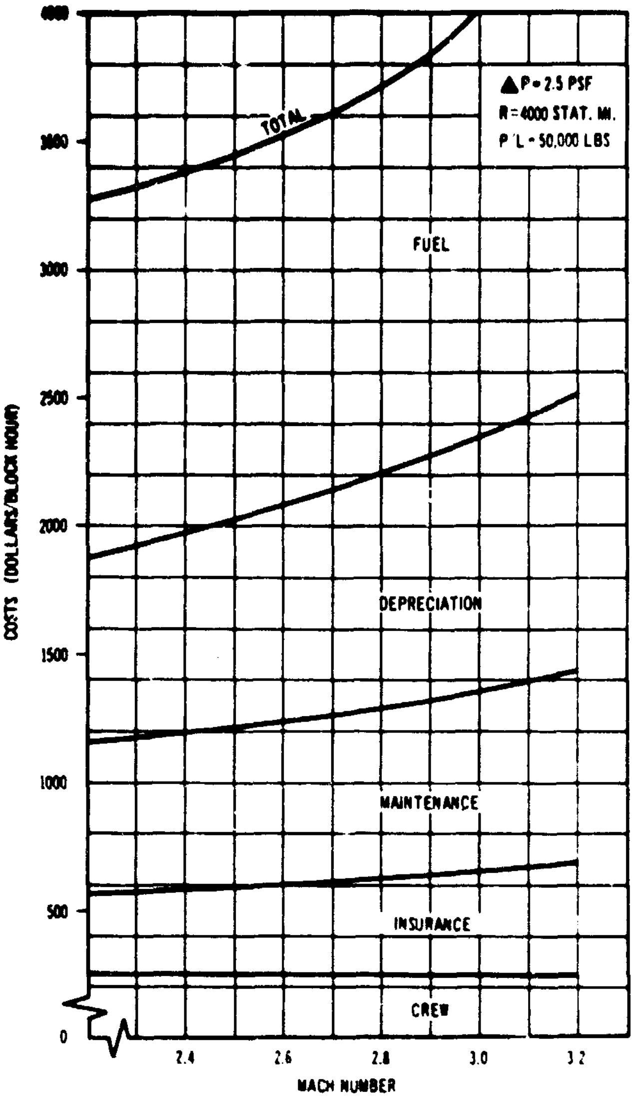

Figure 2-8. Block Hour Costs

capable of speed growth if systems, nonmetallics, fluids, and fuels are improved to commercial service levels for flight at higher speeds.

2.2 VARIABLE SWEEP SELECTION

Aerodynamic studies indicate that there is an optimum wing sweep angle for maximum efficiency at each Mach number (Fig. 2-10). These data indicate that the most efficient use of the fuel will require a wing which will permit the B-2707 to fly near L/D_{max} at each Mach number. The versatility and economics suggested by these data started Boeing on its intensive development of the variable sweep SST.

The choice of variable sweep was made in light of the performance potential, operational flexibility, general suitability for airline use, flying qualities, noise, safety, and operating cost considerations. The Boeing objective is to retain the high level of efficiency of the subsonic jet, while being able to produce maximum efficiency at supersonic speeds. Fig. 2-11 shows the variation of lift (per unit of dynamic pressure, q) with airplane angle of attack. The lift produced at a wing leading edge sweep angle of 30 degrees is substantially greater at all angles of attack than that produced at any greater sweep angle. Wing-sweep angle is a fundamental aerodynamic parameter as unit lift per unit angle

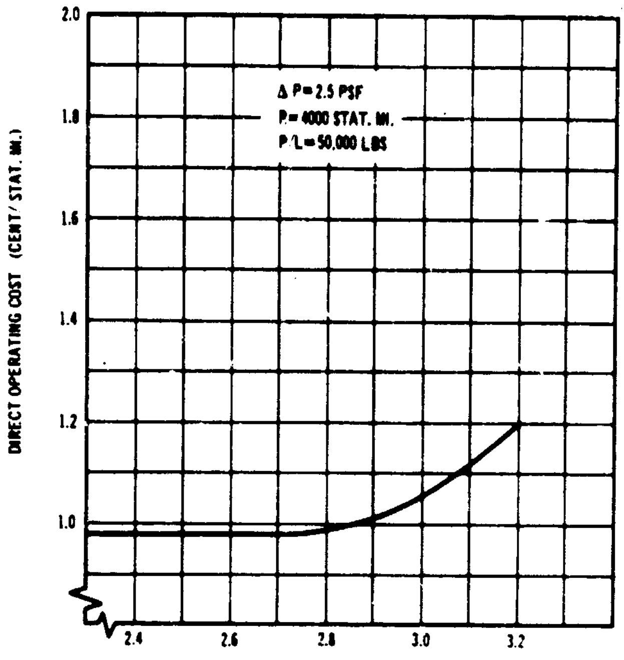

Figure 2-9. Direct Operating Costs (DOC)

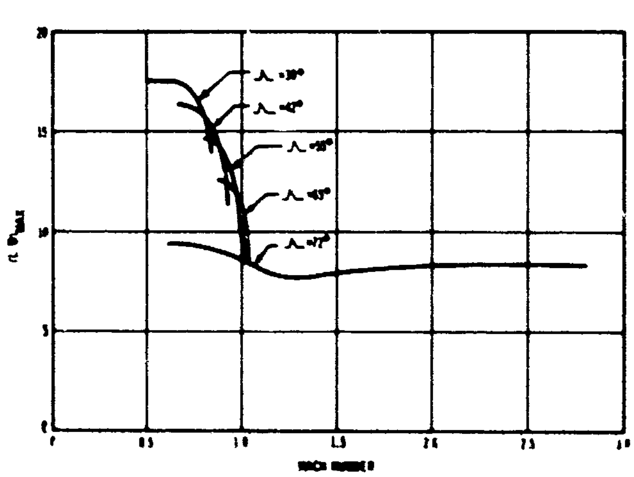

Figure 2-10. Effects of Sweep On Efficiency

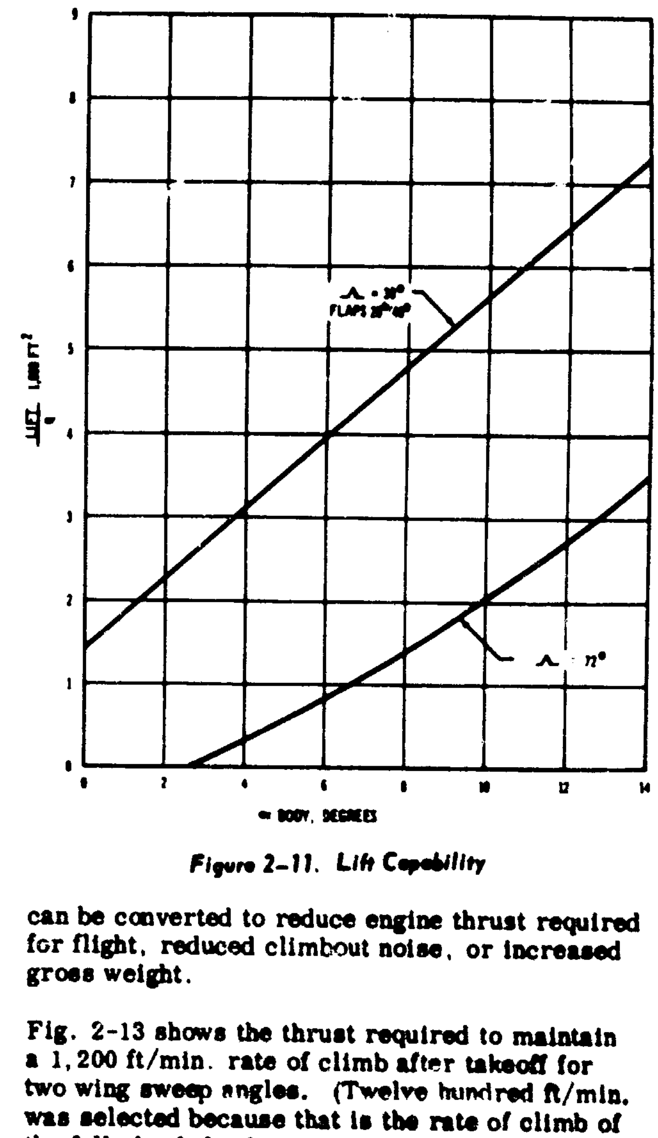

Figure 2-11. Lift Capability

of attack decreases rapidly as wing sweep and therefore span is reduced. Fig. 2-12 shows the variation of lift with drag for two wing sweep angles. The fundamental parameter illustrated here is that aerodynamic efficiency, L/D, is a function of the wing span. The lower the wing-sweep angle, the greater the span and the efficiency. The increased efficiency level can be converted to reduce engine thrust required for flight, reduced climbout noise, or increased gross weight.

Fig. 2-13 shows the thrust required to maintain a 1,200 ft/min. rate of climb after takeoff for two wing sweep angles. (Twelve hundred ft/min. was selected because that is the rate of climb of the fully loaded subsonic intercontinental airplanes.) It would be desirable to compare the thrust required for the two wing sweep angles at a climbout speed comparable to that in present airline use, for example, 200 knots; however, there is not sufficient thrust available to climb at 1,200 ft/min. for the high sweep-low span airplane. A comparison at 250 knots shows that the 30 degrees sweep airplane would require 45 percent less thrust than the 72 degrees sweep airplane. The thrust difference can be converted to acceleration potential, higher climb rate, or lower community noise.

Fig. 2-14 shows the rate of climb as a function of wing sweep angle and/or span. The airplane with the low wing sweep can accept an emergency

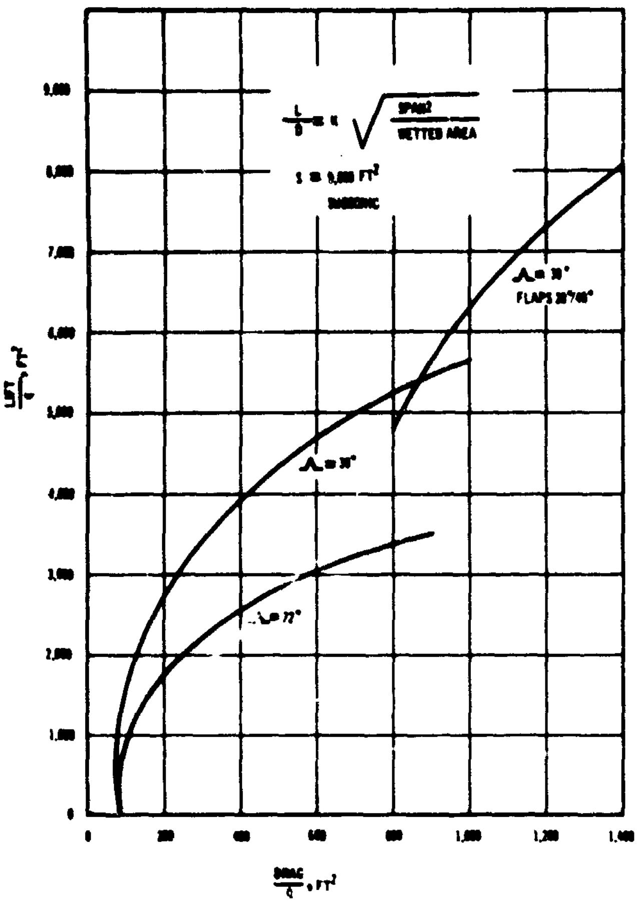

Figure 2-12. Optimum Sweep for Takeoff Efficiency

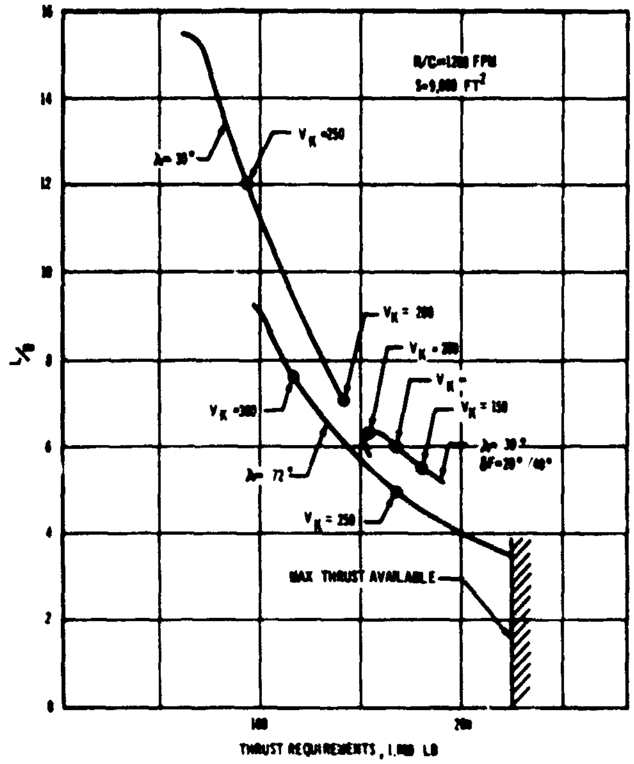

Figure 2-13. Climb Thrust Requirement

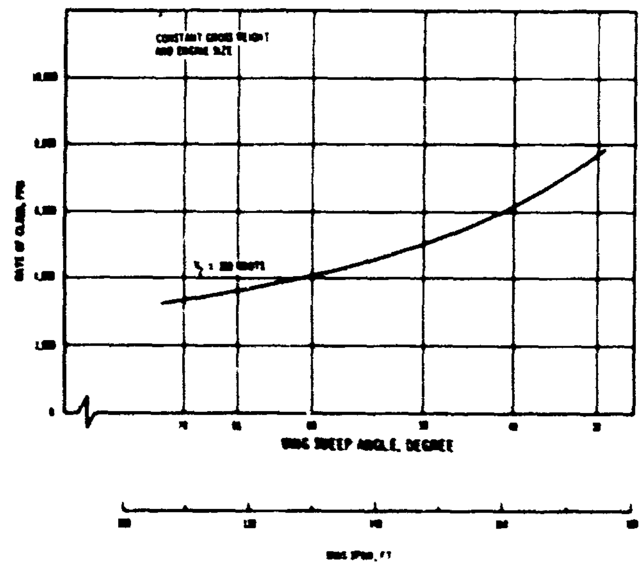

Figure 2-14. Takeoff Rate of Climb

(such as an engine out) with a great deal more safety than one with limited span because it has twice the rate of climb available. The climb rate will have important safety implications in airline operation.

Fig. 2-15 shows the noise under the flight path for two wing sweeps when both are climbing at 1,200 ft/min. If the noise is measured at the condition which limits each airplane performance (10,500 foot field at 86°F for 30 degrees sweep and second segment climb gradient for low span airplanes), the 30 degrees sweep airplane will make 14 PNdb lower noise. The lower noise level for the large span airplane is an important factor in airport and community compatibility.

Fig. 2-16 shows the gross weight that can be lifted from a 10,500 foot FAR field as a function of lift coefficient for variations in wing span or leading edge sweep angle. Also shown is the speed at lift-off. The advantage of large span is evident in its much greater weight carrying ability.

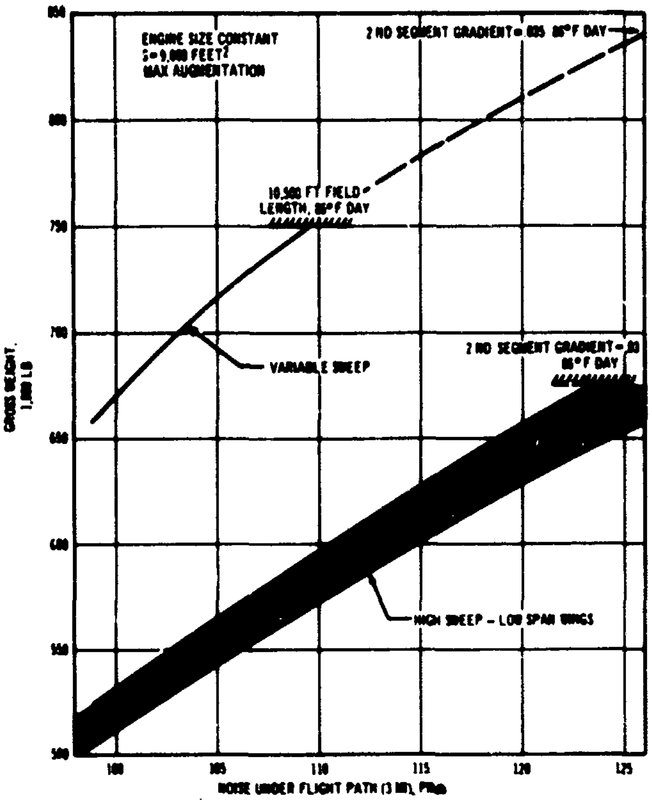

Figure 2-15. Weight-Noise Relationship

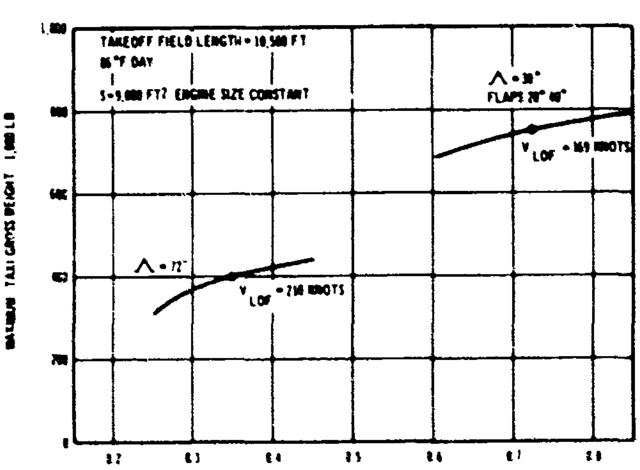

Figure 2-16. Weight Capability

Air maneuvering, subsonic climb, holding at the destination, and flight to an alternate in case of a closed destination require high levels of subsonic aerodynamic efficiency. Fig. 2-17 shows lift-drag ratio as a function of skin friction coefficient

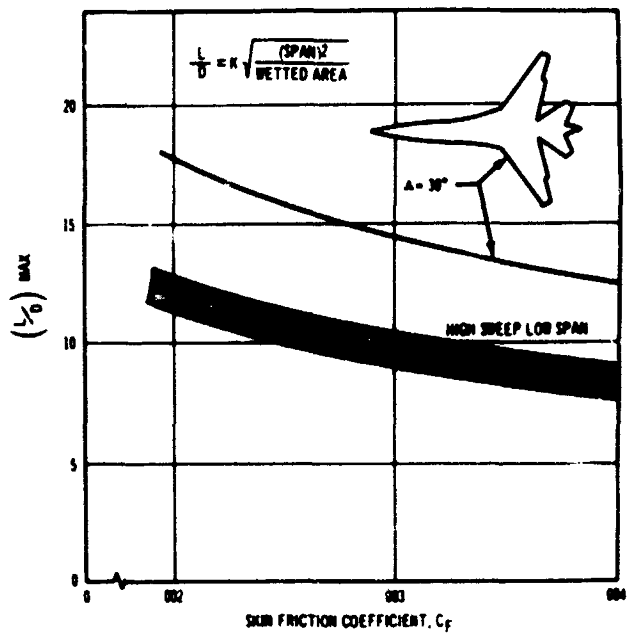

Figure 2-17. Subsonic Aerodynamic Efficiency

for two different wing sweeps. Substantial differences in skin friction coefficient (which will not be present on competing airplanes) still indicate superior performance for the low-wing sweep airplane. This fundamental characteristic can have an important bearing on the operational use, safety, and economy of the airplane.

Inasmuch as it is a possibility that supersonic flight over land masses may be limited because of sonic boom, it is equally important to be able to cruise at high-subsonic speeds without range penalty. Fig. 2-18 shows the variation of total range with a subsonic cruise leg at the start of the mission for two wing sweeps. When the wings are fixed at 72 degrees there is a range loss of 150 mi if the airplane cruises for 400 n.mi. subsonically at the beginning of the mission (a payload penalty of 7,000 lbs if range is held constant). There is essentially no range and/or payload loss if the wings are at 30 degrees of sweep for the subsonic part of the mission.

The ride qualities of a supersonic transport are of high interest to the airlines, both from passenger appeal and possible structural fatigue. Fig. 2-19 shows the gust response variation with wing loading and sweep angle for representative conditions. The wing loading and sweep angle of the B-2707 offer ride quality in cruise and at the more critical transonic speeds, superior to the 707-300 and also

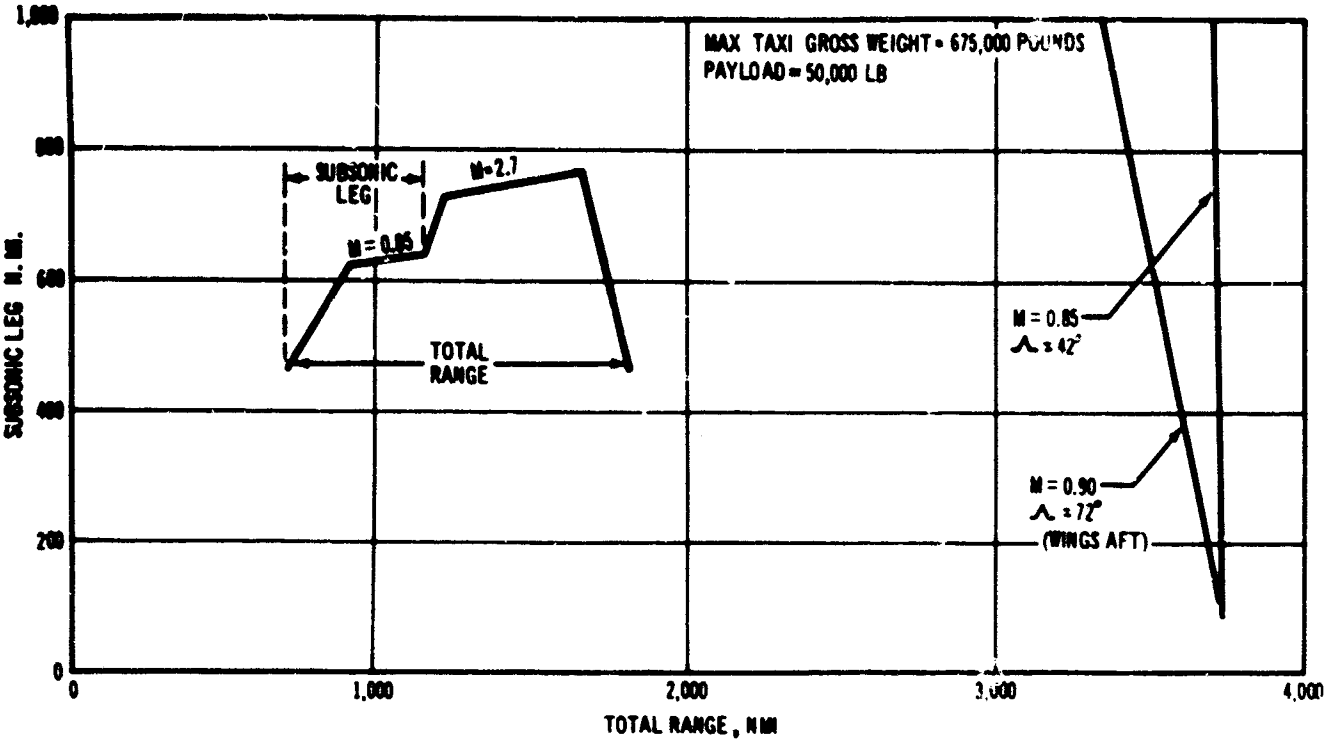

Figure 2-18. Subsonic Range

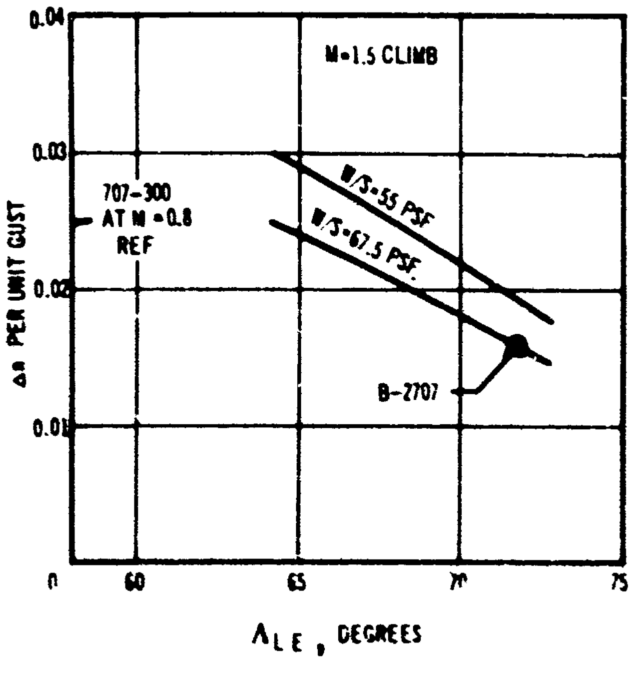

Figure 2-19. Gust Response

superior to lower wing loading/lower sweep supersonic airplanes. Since the Δg loading is lower, there will be a definite reduction in fatigue loading to the wing with 72 degrees of sweep.

The landing characteristics of a commercial supersonic transport should cause the airline pilot no more concern than present day commercial jet aircraft. The airplane should have forgiving handling qualities, the speed should be low for safety and maintenance reasons, the airplane should be speed stable, and its acceleration characteristics for missed approaches should be good.

Fig. 2-20 shows the thrust required as a function of approach speed for a wing sweep of 30 degrees and a higher sweep angle typical of fixed wing designs. The shapes of the curves are quite different. When the wings are at 30 degrees sweep during the landing approach, the airplane is speed stable down to 120 knots, and at 120 knots the attitude would be about 14 degrees nose up. For the high-sweep low-span airplane, the pilot would have to reverse his normal habits because

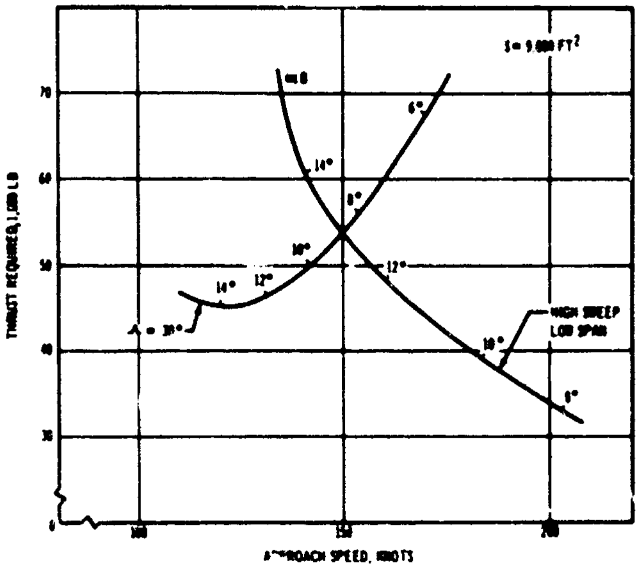

Figure 2-20. Speed-Stability

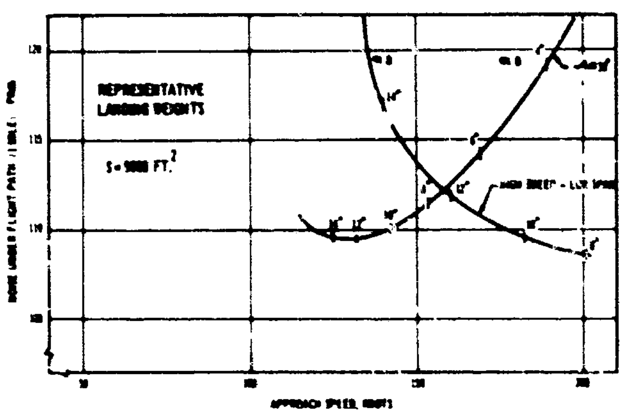

Figure 2-21. Landing Noise

the airplane is unstable with speed. In order to achieve approach speeds as low as 140 knots, the attitude would be 14 degrees and the pilot would have to add power at the rate of 2,000 lbs per knot for each knot he was lower in speed. For equal approach speeds at representative landing weights, the 30 degrees sweep wing airplane has about 3 degrees lower attitude than the highly swept wing and for equal attitude (14 degrees) has a 20 knot slower approach speed. The slower speed and lower attitudes of a variable sweep airplane will have very important safety and economic benefits to the airline operator.

Noise on the landing approach is a critical problem at many airports today. Fig. 2-21 shows approach noise measured at 1 mi from touchdown on a 3 degrees glideslope as a function of approach speed for airplanes with wings at 30 degrees and for higher sweep-low span designs. For equal airplane attitudes of 14 degrees, the 30 degrees sweep airplane would produce 7 PNdb less noise than one with wings fixed back at representative landing weights. At equal speeds (140 knots) the 30 degrees swept wing would also produce 7 PNdb less noise. These low values of approach noise for the 30 degrees sweep wing airplane are considerably below current commercial jet aircraft whereas the low span airplane would offer no noise improvement.

Ground effect is a fundamental characteristic caused by the ground turning the deflected air from the wing. The ground thus not only increases lift but causes a nose-down pitching moment. When the nose-down pitching moment is trimmed out, the ground effect is not effective in producing either a significant increase in lift or reduction in angle required for flare when flying on an instrument approach on 3 degrees glideslope. These landing characteristics are very similar to those experienced by the large subsonic jet transports where a small flare is made just at touchdown to arrest the sink speed. It has been shown that the airplane which can match its wing span and sweep to each flight condition has superior efficiency, safety, lower noise, more passenger appeal due to better ride quality and lower attitudes, and will result in lower maintenance costs because of its inherently lower speeds for takeoff and landing. Boeing has selected variable sweep because it has forgiving handling qualities, is a better neighbor at the airports, and has more economic potential through future growth.

2.3 PAYLOAD CAPABILITY

Advanced technology subsonic jets, such as the Boeing Model 747, are being offered to the airlines with payload capabilities up to 500 passengers to accommodate the large volume of traffic forecast for the 1970 to 1980 time period. This large increase in air travel, which is forecast to double by 1970 and triple by 1975 over 1965, requires large capacity aircraft to prevent air traffic congestion. The 747 will permit the airlines to satisfy the market demand for air travel without having to add flight frequencies appreciably until the late 1970's or early 1980's. Fig. 2-22 shows

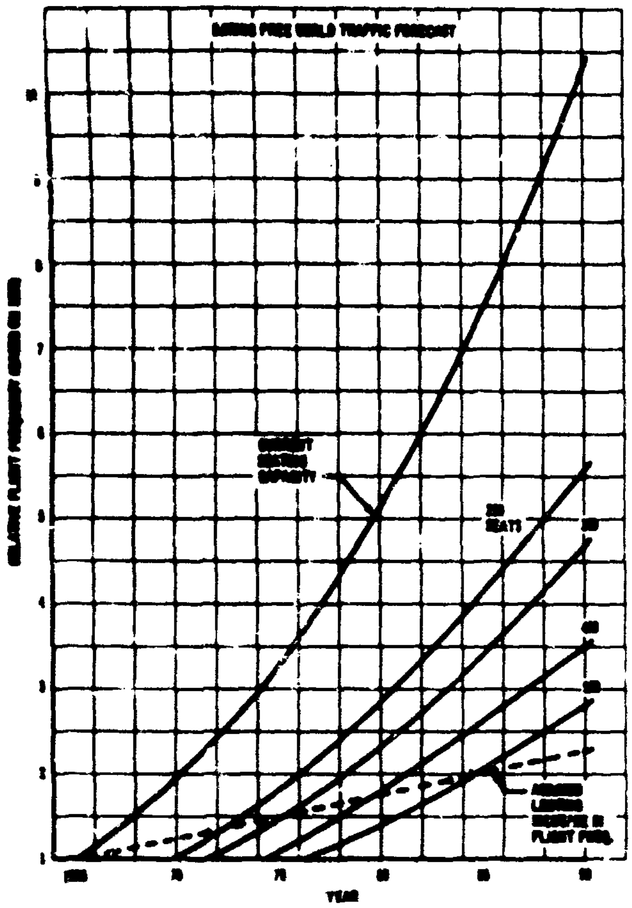

Figure 2-22. Relative Flight Frequency

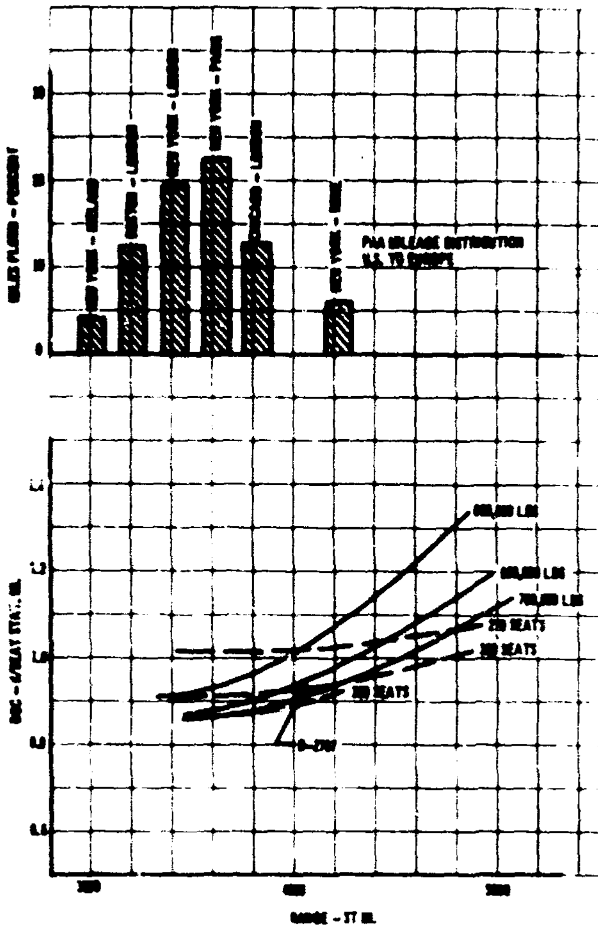

Figure 2-23. Parametric Relationships

the relative flight frequencies required to accommodate the forecast traffic at various seating capacities. It may be noted that if there were no increase in aircraft size, the current jets would have to quintuple the flight frequencies by 1980. The dotted line shows the assumed upper limit of growth in frequencies. The supersonic sizing to prevent an excessive growth in frequency must be capable of offering at least 300 seats in 1975. This tube sizing is deemed necessary from the airlines' viewpoint to minimize change of guage from connecting flights.

Fig. 2-23 shows the parametric relationship between payload, gross weight, range, and direct operating cost. The design points are related to typical U.S. - Europe route mileages and frequencies as shown. The B-2707 design was selected to meet the FAA range requirement with optimum economics and to accommodate the forecast volume of traffic with the optimum payload/frequency relationship.

Fig. 2-24 shows a comparison of the seat mi direct operating cost versus range for the Boeing Models 2707, 707-320B, 747-type, and the English-French Concorde. The B-2707 has lower seat mi costs than either the 707-320B or the Concorde by a substantial margin and it closely approaches that of the 747. A comparison of the airplane mi costs is shown in Fig. 2-25. These data indicate that the B-2707 will operate at lower dollar/mi costs than the 747-type at ranges greater than about 1,500 mi.

Fig. 2-26 shows the profit potential as a function of range for the Concorde, 707-320B, 747-type

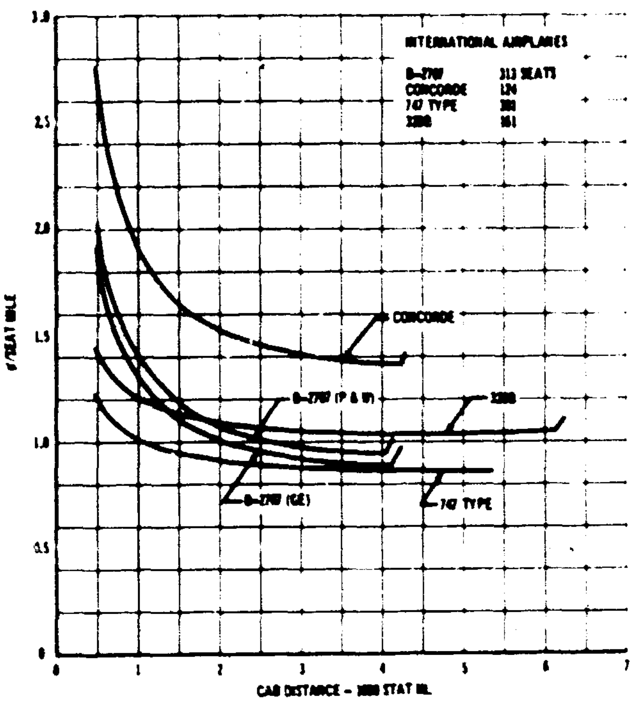

Figure 2-24. Direct Operating Cost Comparison

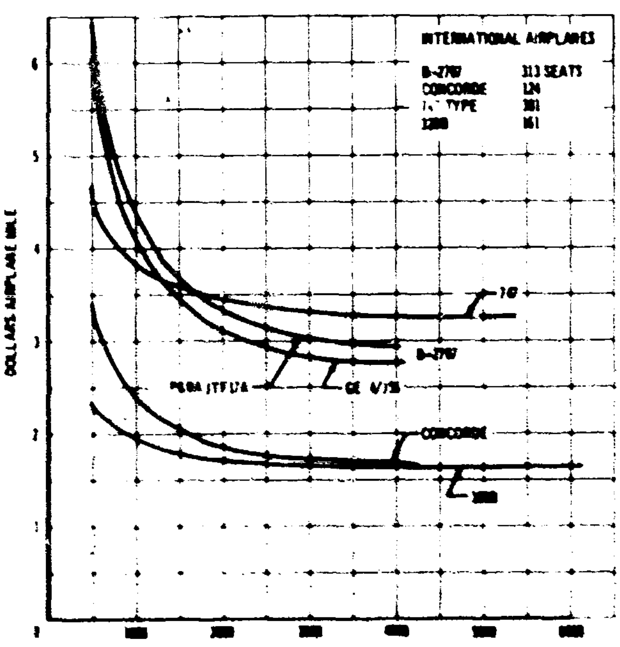

Figure 2-25. Direct Operating Cost/Airplane Mile

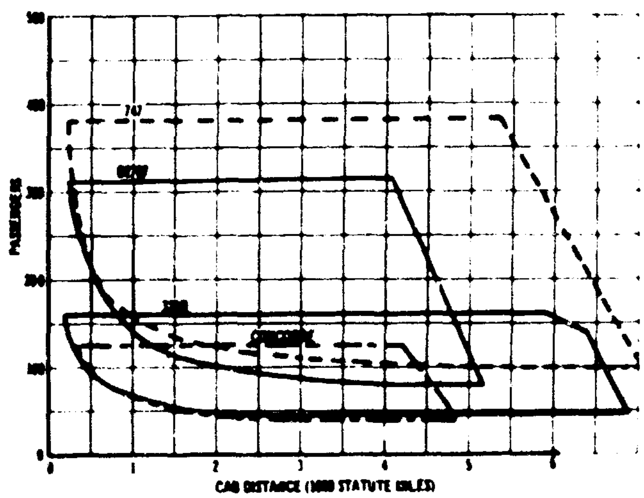

Figure 2-26. Profit Potential Comparison

and 2707. The lower line represents breakeven load, the upper line is airplane capacity, and the area bounded represents profit potential at equal fares. This illustrates the high profit potential of the B-2707 compared with the 320B and Concorde.

A fare differential, as expected for the faster B-2707 would effectively expand its profit potential. If all first-class traffic travels in the B-2707, and the subsonics are relegated to all-coach fares (substantially less than SST tourist fares) then the profit potential of the B-2707 is favorable even compared with the 747-type. Fig. 2-27 shows the relationship between total operating cost per revenue passenger mi and passengers per airplane for the Concorde, 747-type and B-2707. At the anticipated average yield of the mixed-class SST and the all-coach subsonic, the profitability of the B-2707 becomes evident.

2.4 RANGE CAPABILITY

Fig. 2-28 shows the principal routes that will be suitable for B-2707. The East Coast to various European destinations will have great competitive appeal. Fig. 2-29 shows the range requirements for the North Atlantic routes. The great circle distances shown will not provide all-weather summer operation. Approximately 500 mi additional range capability is required to provide two-way year-round operation at constant payload because of prevailing winds. The band shown labeled 4,200 st mi indicates the markets that could be reached with that design range.

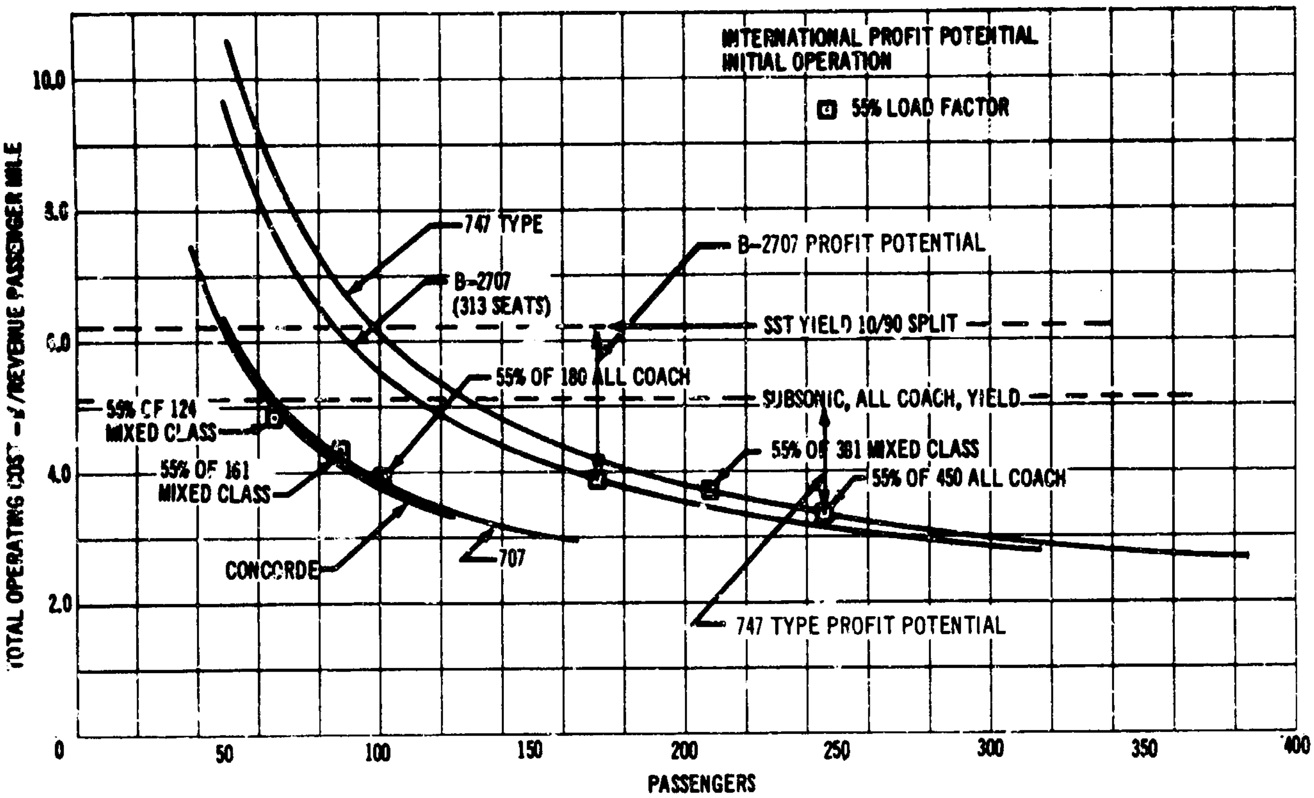

Figure 2-27. Comparative Profit Potential B-2707, Concorde, 747, 707

The design goals are: an all-weather full-passenger payload, New York to Paris, 3,740 st mi; and a moderate passenger payload for New York to Rome, 4,360 st mi. The design payload discussed in Sec. 2.3 together with the design range goal establishes the payload-range curve shown in Fig. 2-30. It should be noted that the maximum allowable payload of 75,000 pounds can be carried 3,800 st mi, and that the fuel volume limit is for a payload of 20,000 lbs at a range of 5,125 st mi. Fig. 2-31 shows the P&WA engine curve, which is approximately 60 mi less range.

2.5 GROSS WEIGHT

The selection of the 675,000 lb B-2707 gross weight resulted from a coupling of the range-payload objectives and the economic performance required to make the airplane competitive with the 707-320B and 747 airplanes. Historically each new generation of airplane has had to increase speed, payload and gross weight to remain competitive in seat-mi costs. The 747 has increased the payload and gross weight without substantially changing the cruise speed. This change in payload/gross weight has reduced the seat mi cost of the 747 over the 707-300 series by approximately 20 percent. The selection of the gross weight for the B-2707 is influenced by:

- Payload-range goals
- Cruise speed
- Sonic boom
- Airport and community noise
- Low-speed requirements

The previous discussion, Sec. 2.3, Payload Capability, indicated that the B-2707 at payloads of 50,000 lbs or greater, would be competitive with the 707-300 series airplanes and near the projected 747 seat-mi costs. Selections of the cruise speed, Sec. 2.1, the payload, range, and configurations concept provides the necessary constants to develop a series of parametric data for the selection of the gross weight. Fig. 2-32 shows the airframe-engine match for the 675,000 lbs design gross weight. This curve

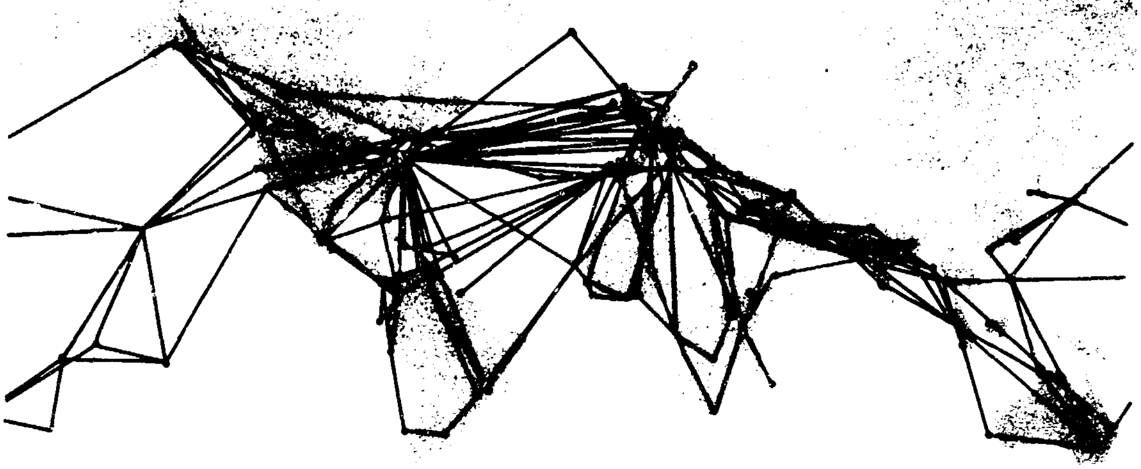

Figure 2-28. Free World SST Routes

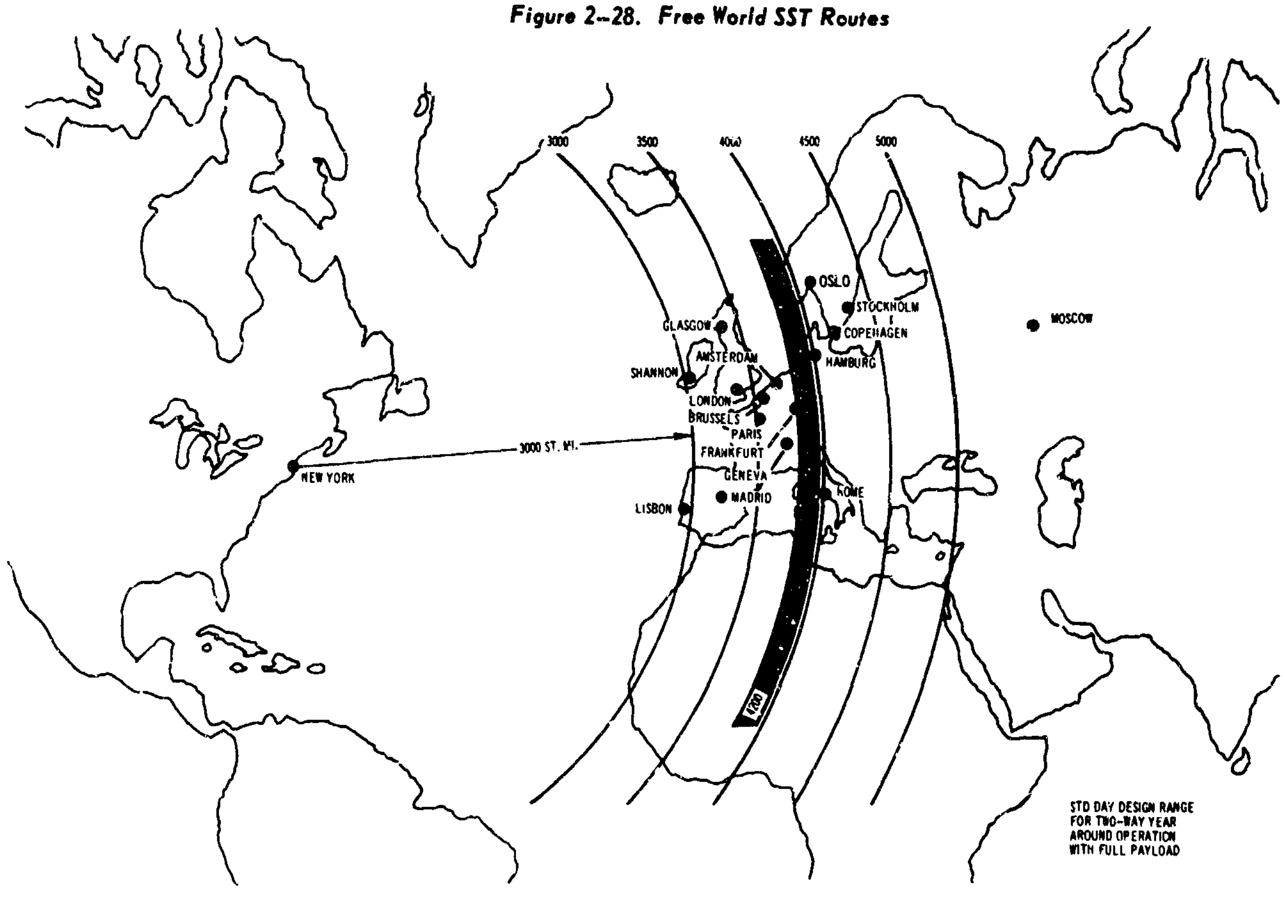

Figure 2-29. North Atlantic Range Requirements

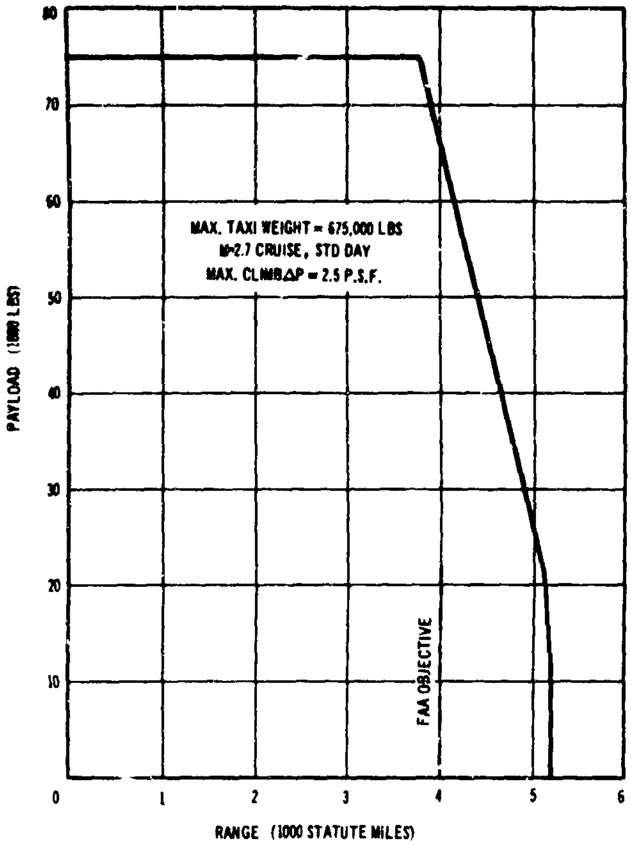

Figure 2–30. B–2707 (GE) Intercontinental Payload–Range

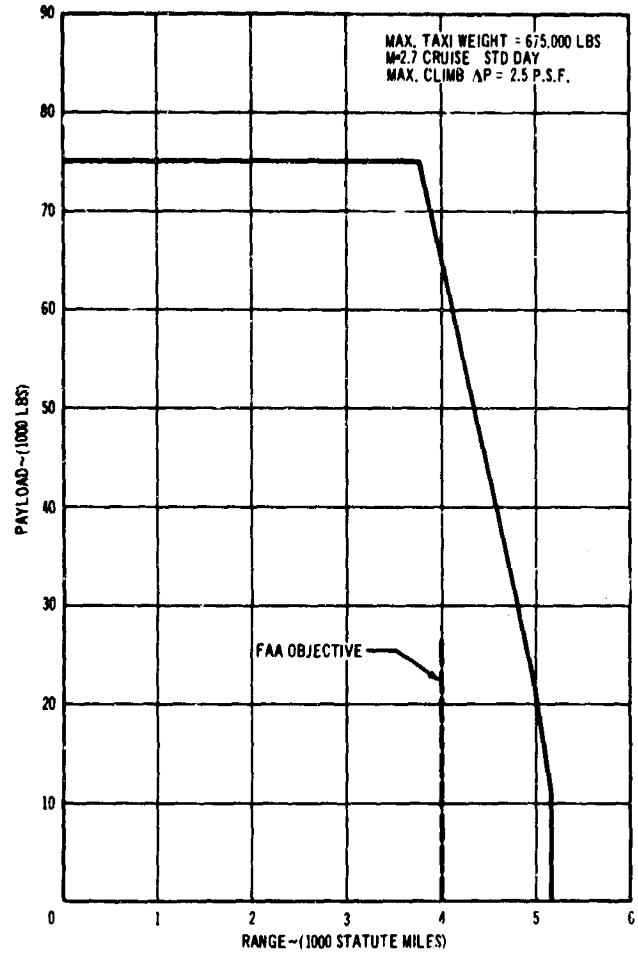

Figure 2–31. B–2707 (P&WA) Intercontinental Payload–Range

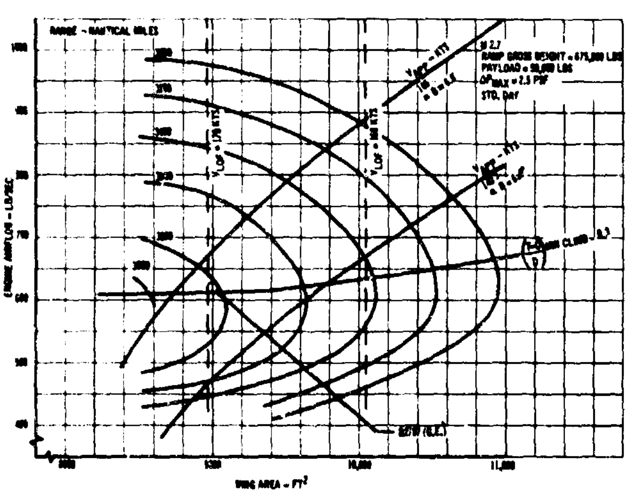

Figure 2–32. Airframe–Engine Match

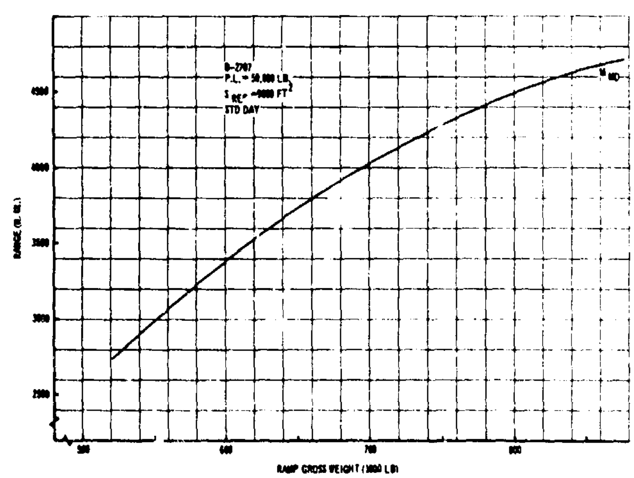

Figure 2–33. Maximum Range

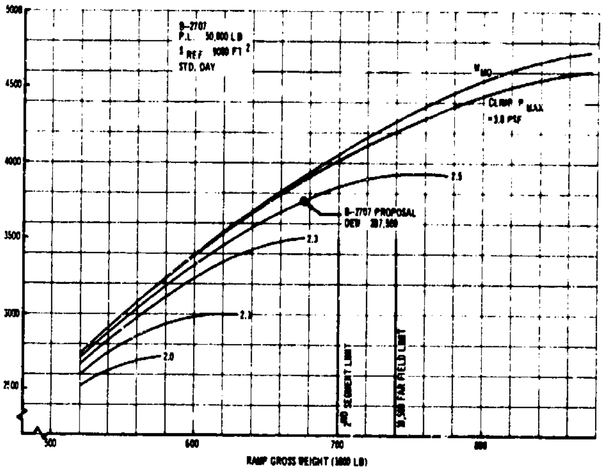

Figure 2-34. Operating Restrictions

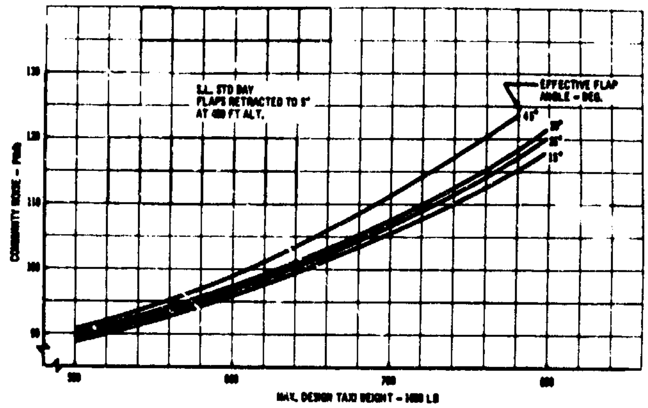

Figure 2-35. Community Noise

shows that the design goals have been obtained at the design weight, within the frame of operating restrictions. A cross plot of a series of these curves provides the range/gross weight curve shown in Fig. 2-33.

Fig. 2-33 does not show the effects of airplane operating restrictions. Fig. 2-34 shows the sonic boom overpressure lines added and the takeoff limit cutoff. It can be seen that the range that can be flown for a given gross weight is sensitive to the sonic boom overpressure restrictions for that particular mission. It should also be noted that the 10,500 ft FAR T.O. field length and second segment climb limit is well above the B-2707 design gross weight.

The flap system used on the B-2707 provides a large selection of low speed operating parameters. Fig. 2-35 shows the variations in community noise with flap setting as a function of gross weight. The flap variations provide the airplane with the ability to match the noise requirements for a given airport with the gross weight required on that particular flight.

CONTENTS

3.0 AIRPLANE DESCRIPTION

The B-2707 is an airplane constructed principally of titanium and featuring a variable sweep wing. Its design cruise speed is Mach 2.7.

The airplane accommodates either General Electric or Pratt and Whitney Aircraft engines as shown in the general arrangements. See Figs. 3-1 and 3-2.

SEE FULL SIZE DRAWING IN POCKET INSIDE BACK COVER

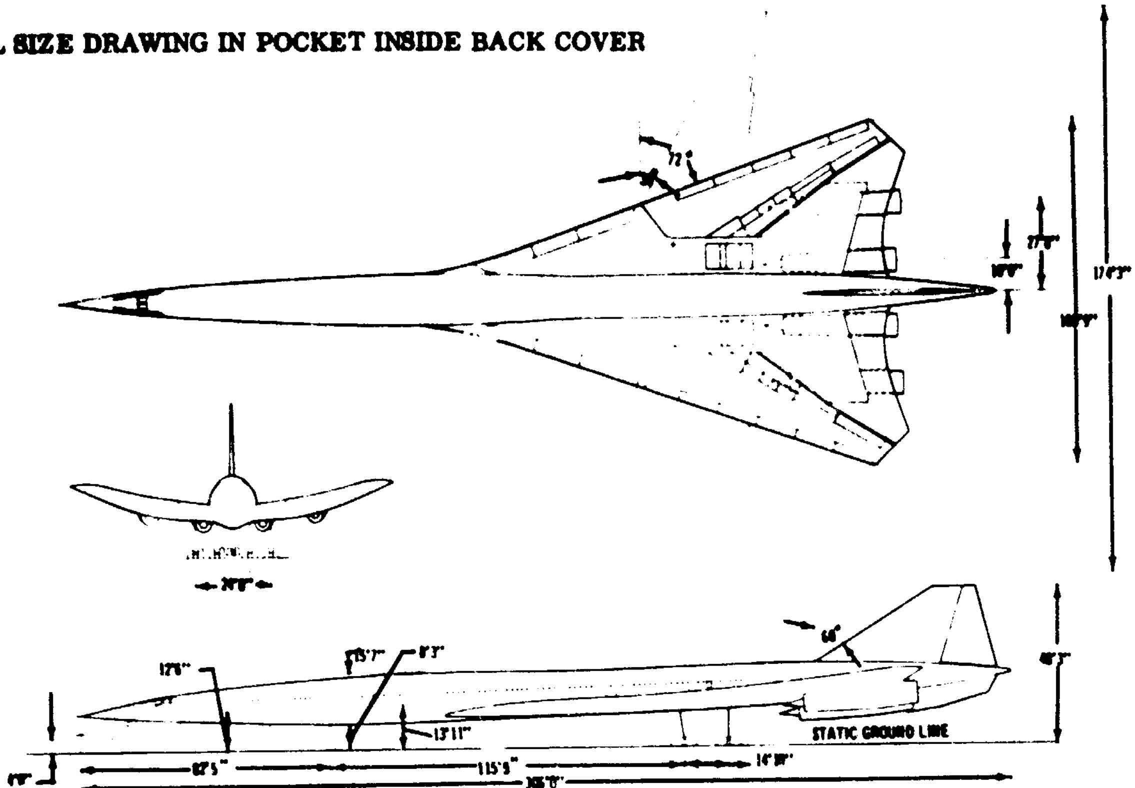

Figure 3-1. General Arrangement Boeing Model 2707 (GE)

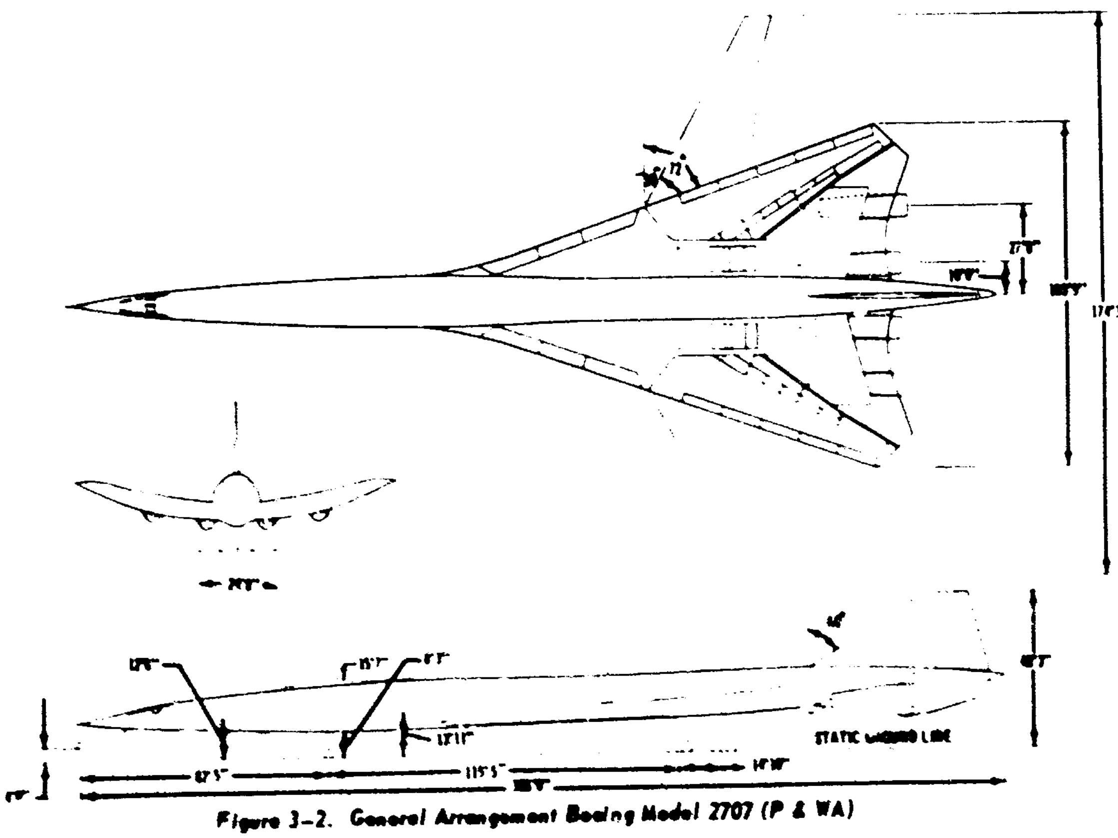

Figure 3-2. General Arrangement Boeing Model 2707 (P & WA)

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Table 3-A summarizes the physical characteristics of the airplane.

The design incorporates the desirable features developed by the NASA-sponsored SCAT studies conducted in 1963 which compared delta and variable sweep types. In addition, an excellent high-lift system provides outstanding low-speed performance and growth potential.

Table 3-A. B-2707 Physical Characteristics

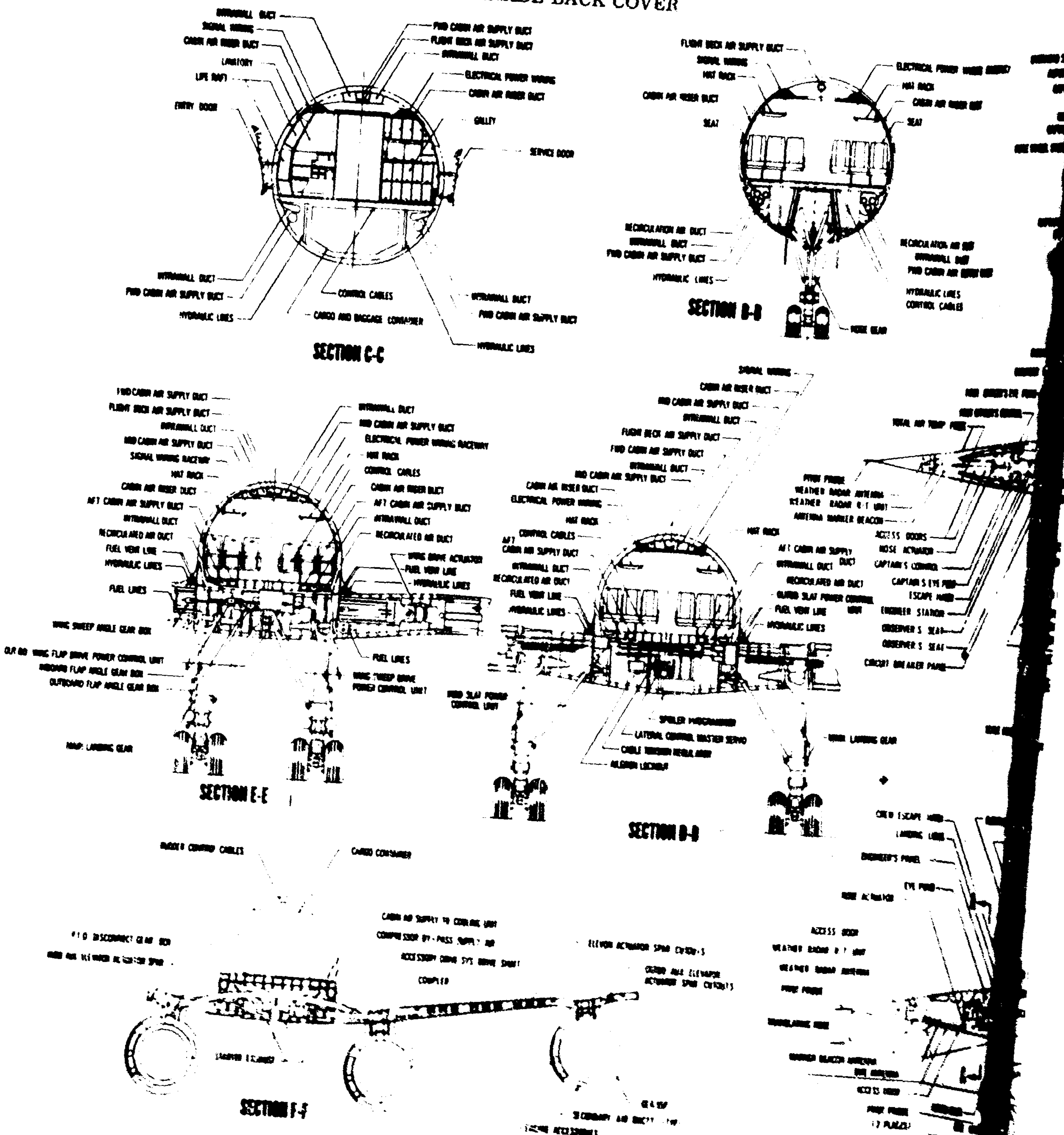
WEIGHTS	MAX. DESIGN TAXI WEIGHT	675,000 Lbs.				
	NOMINAL PAYLOAD	50,000 Lbs.				
	OPERATIONAL EMPTY WEIGHT	287,500 Lbs. G.E.				
		286,000 Lbs. P.W.				
	FUEL CAPACITY	374,700 Lbs.				
CENTER OF GRAVITY DATA	Most Fwd. C. G.	[illegible]% Ref. Length (Gear Up, Wing Fwd)				
	Most Aft C. G.	60% Ref. Length (Gear Up, Wing Aft)				
	Operational Empty Weight	G.E. 65.1% Ref. Length (Vertical C.G. @ W.L. 210 (Wing Fwd, Gear Down)				
		P.W. 65.9% Ref. Length (Vertical C.G. @ W.L. 210 (Wing Fwd, Gear Down)				
	Design Taxi Weight	63.9% Ref. Length (Vertical C.G. @ W.L. 214 (Gear Down, Wing Aft)				
WING	Gross Wing Area	9,000 Ft²				
	@ Λ_{LE} = 72°					
	Span	105.74 Ft.				
	Ref. Length for Area - 9000 Ft²	184.06 Ft.				
	Aspect Ratio	1.24				
	Taper Ratio	29.3%				
	Pivot Location	42.8% Chord and 29.3% Semi-Span				
	Dihedral Angle	0°				
	Angle of Incidence of Root to Fuselage Ref. Line	-4.710° (Defined @ .100 Semi-Span)				
	Angle of Incidence of Tip to Fuselage Ref. Line	-4.960° (Defined @ 1.0 Semi-Span)				
	Airfoil Section at Side of Body	B733-1 t/c Max = 0.0270				
	Airfoil Section at 0.293 b/2	B733-2 t/c Max - 0.0285				
	Airfoil Section at 0.60 b/2	B733-3 t/c Max - 0.0280				
FLAPS AND CONTROL SURFACES (DEFINED FOR LEADING EDGE SWEEP = 30°)	Surface	INBOARD FLAPS	OUTBOARD T.E. FLAPS	L.E. SLATS	AILERONS	SPOILERS
	Type	Triple Slotted	Double Slotted			Segmented
	Distance from ℄ of Airplane to Inb'd Edge	8.5 Ft	18.3 Ft	12.0 Ft	60.2 Ft	23.8 Ft
	Distance from ℄ of Airplane to Outb'd Edge	16.80 Ft	60.2 Ft	87 Ft	87 Ft	60.2 Ft
	Max Deflection	40°	30°	35-30	±25°	45°
	Deflection for Takeoff	40°	As Reqd.	25°		
	Deflection for landing	40°	As Reqd.			
	% Wing Chord		30%/15%		34%	15%
	% Wing Area Affected		68%			
	Area	210 Ft²	604 Ft²	613 Ft²	120 Ft²	236 Ft²
			TOTAL			
HORIZONTAL TAIL	Area (Projected) (Exposed)		349.9 Ft			
	Span, Total		33.37 Ft			
	Aspect Ratio (Based on Projected Area)		3.49			
	Incidence to Fuselage Ref. Line (Neutral Position)					
	Airfoil Section					
	Thickness Ratio					
	Sweep Angle (Leading Edge)		55°/60°			
	Mean Aerodynamic Chord (M.A.C.)		20.40 Ft			
	Distance to Leading Edge M.A.C. from Leading Edge Root Chord		21.98 Ft			
	Location of M.A.C. from Thrust Line		6 Ft Above			
	Dihedral Angle (Effective)		7-1/2°			
	Taper Ratio		0.15			
VERTICAL TAIL	Area		875 Ft²			
	Span		23.17 Ft			
	Aspect Ratio		0.615			
	Airfoil Section		Hexagonal			
	Thickness Ratio at Body		0.030			
	Thickness Ratio at 1.0 Span		0.030			
	Sweep Angle (Leading Edge)		60°			
	Mean Aerodynamic Chord (M.A.C.)		42.44 Ft			
	Distance to Leading Edge M.A.C. from Leading Edge Root Chord		15.97 Ft			
	Location of M.A.C. from Thrust Line (of Outboard Engine)		27.67 Ft			
	Taper Ratio		0.238			
WETTED AREA (EXPOSED SURFACE AREA)			GE	PW		
	Fuselage		9606 Ft²	9606 Ft²		
	Wing (Including Strake & Horizontal Tail)		14070 Ft²	13947 Ft²		
	Tails		2162 Ft²	2162 Ft²		
	Propulsion Pods		2700 Ft²	2800 Ft²		
	Fences		230 Ft²	270 Ft²		
	Total		29,808 Ft²	28,800		

The inboard profile drawings (Figs. 3-3 and 3-4) present the internal features of the airplane. The compact relationship of the landing gear, wing-box, and wing-pivot provides a rigid, efficient structure for the fundamental support of the airplane. Equipment has been located to permit a maximum degree of safety and accessibility for maintenance.

Where practical, equipment items have been located such that their contribution to noise within inhabited areas of the aircraft are minimized.

A pocket on the back cover of this document contains four large general arrangement and inboard profile drawings.

SEE FULL SIZE DRAWING IN POCKET INSIDE BACK COVER



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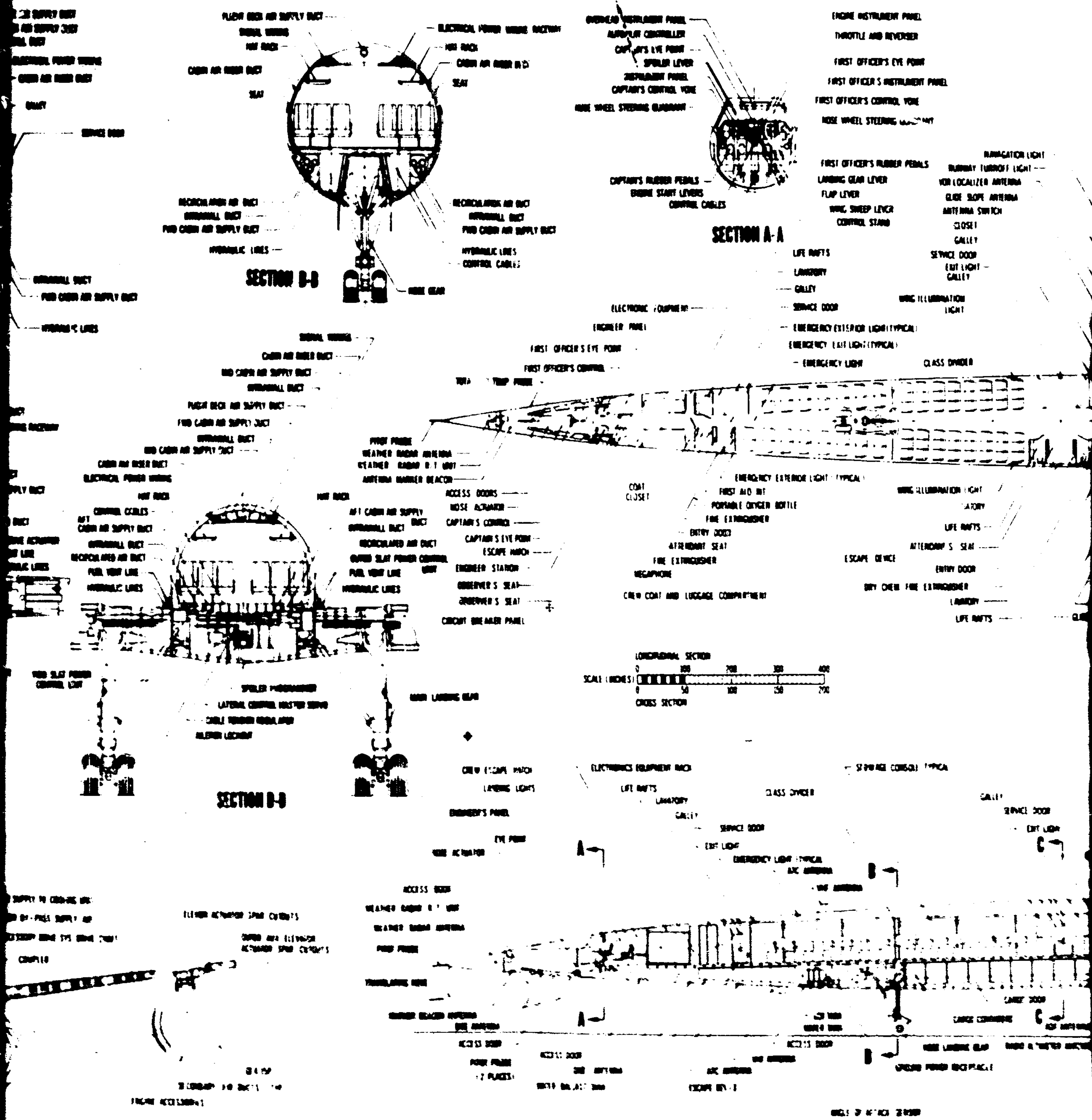
INSIDE BACK COVER



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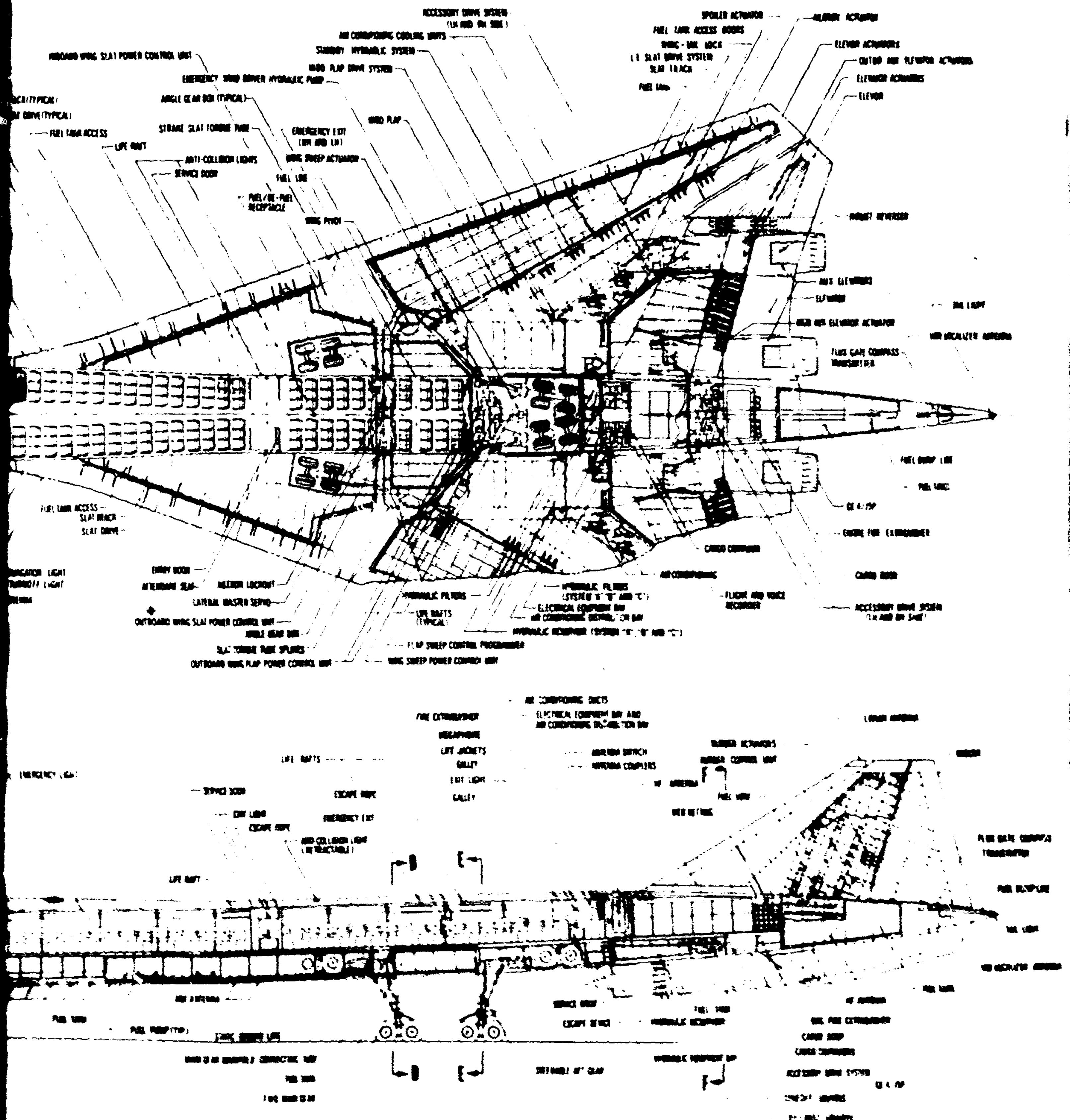
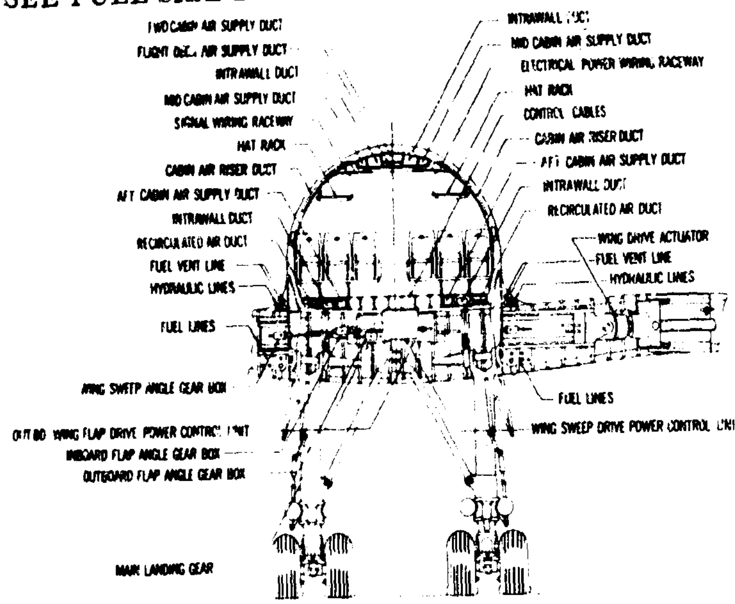


Figure 3-3. Inboard Profile (GE)

SEE FULL SIZE DRAWING IN POCKET INSIDE BACK COVER



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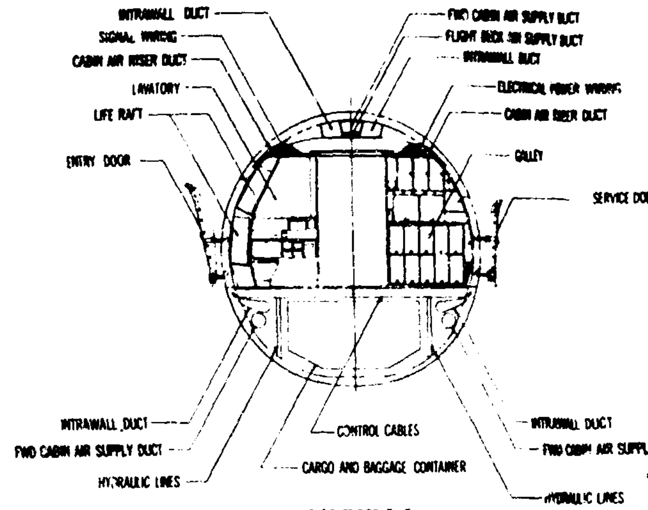

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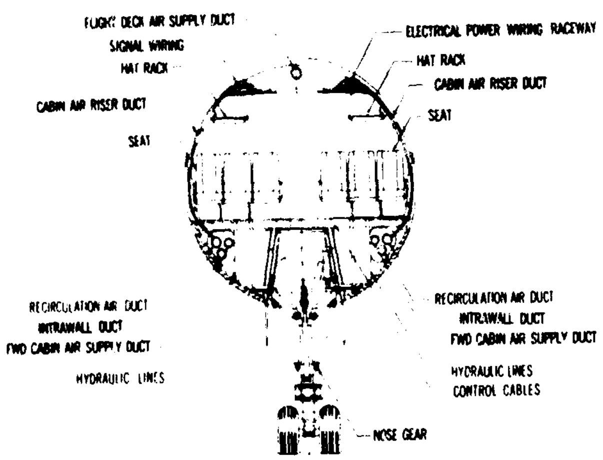

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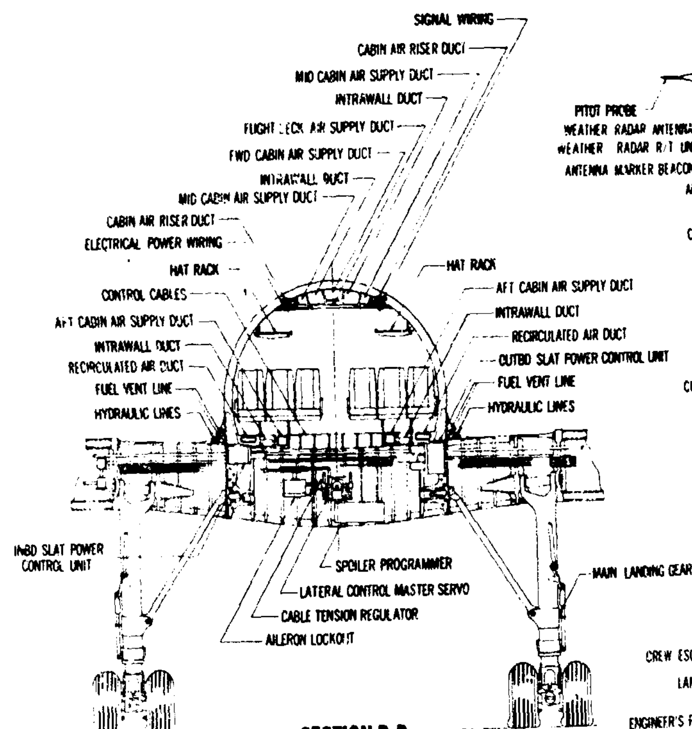

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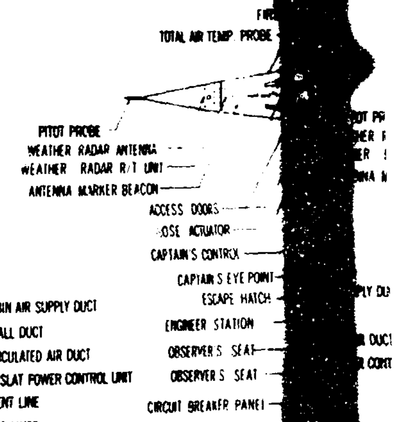

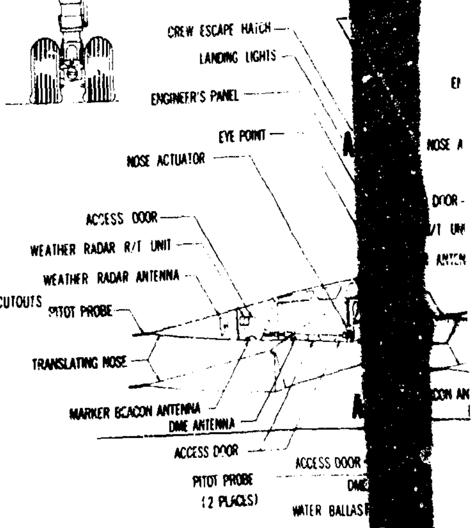

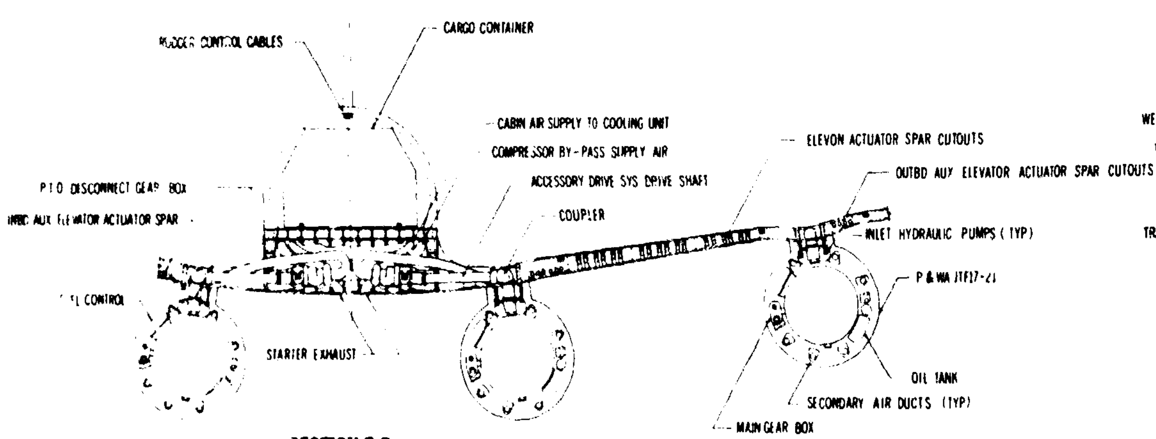

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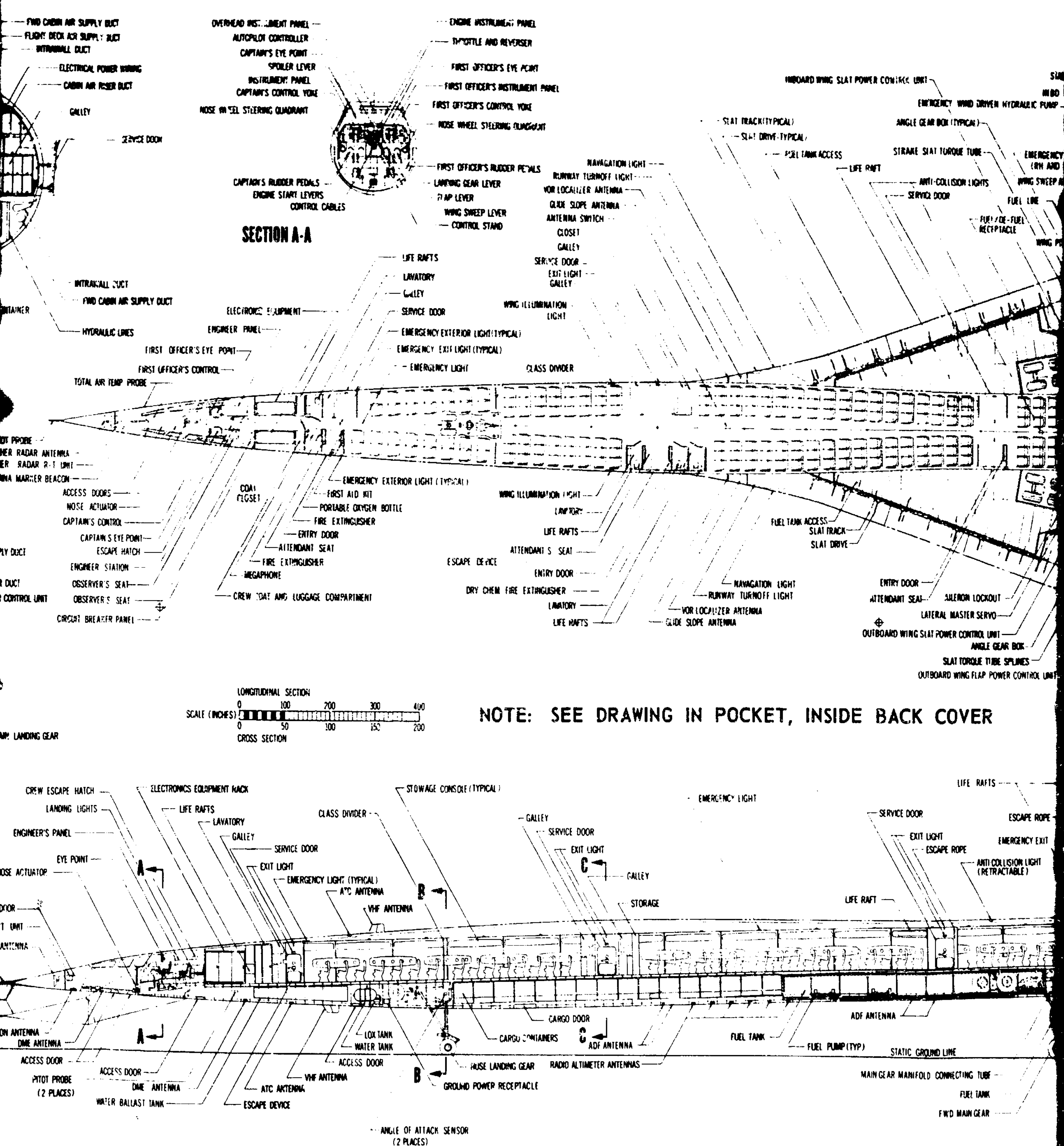

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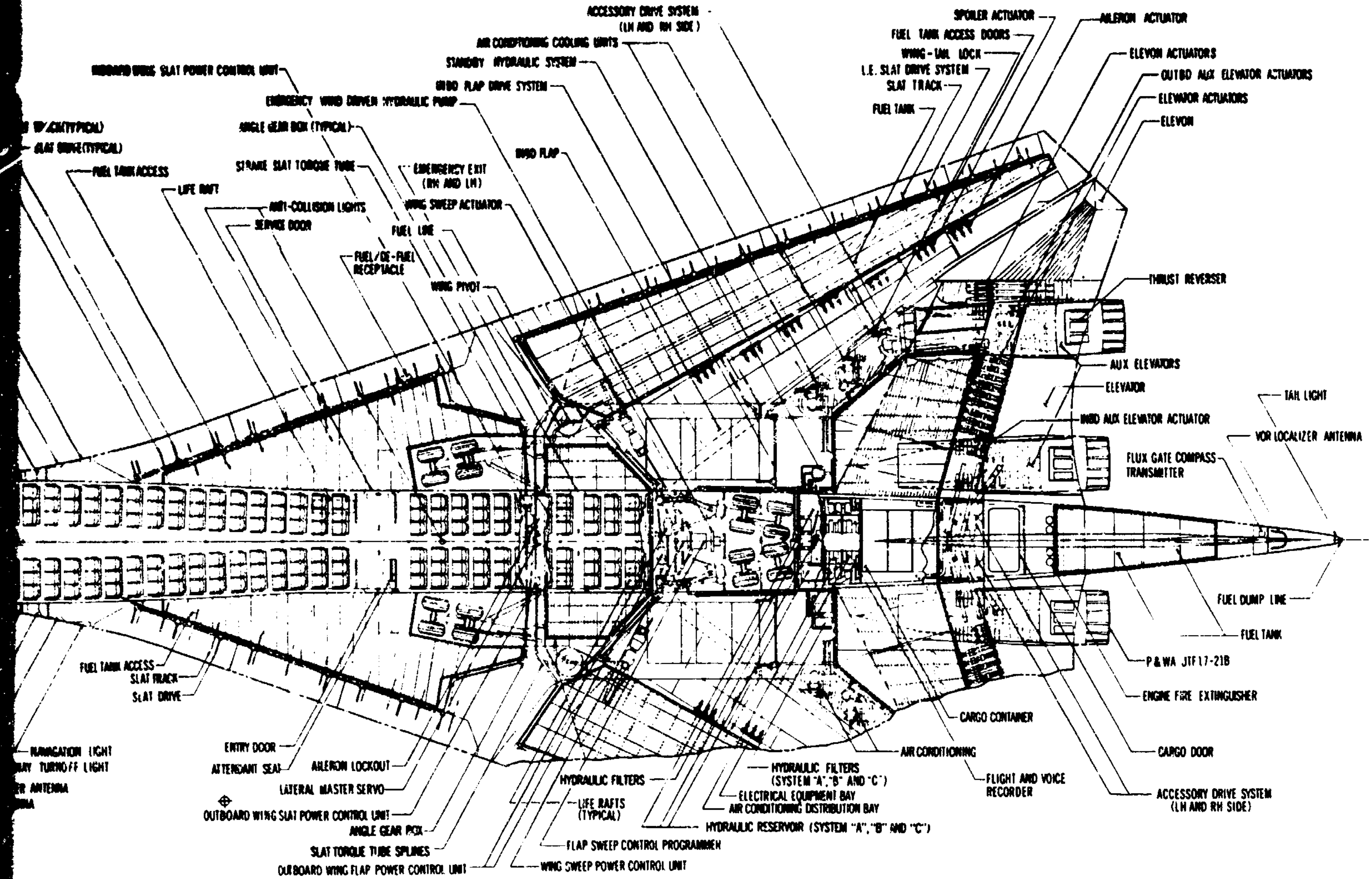

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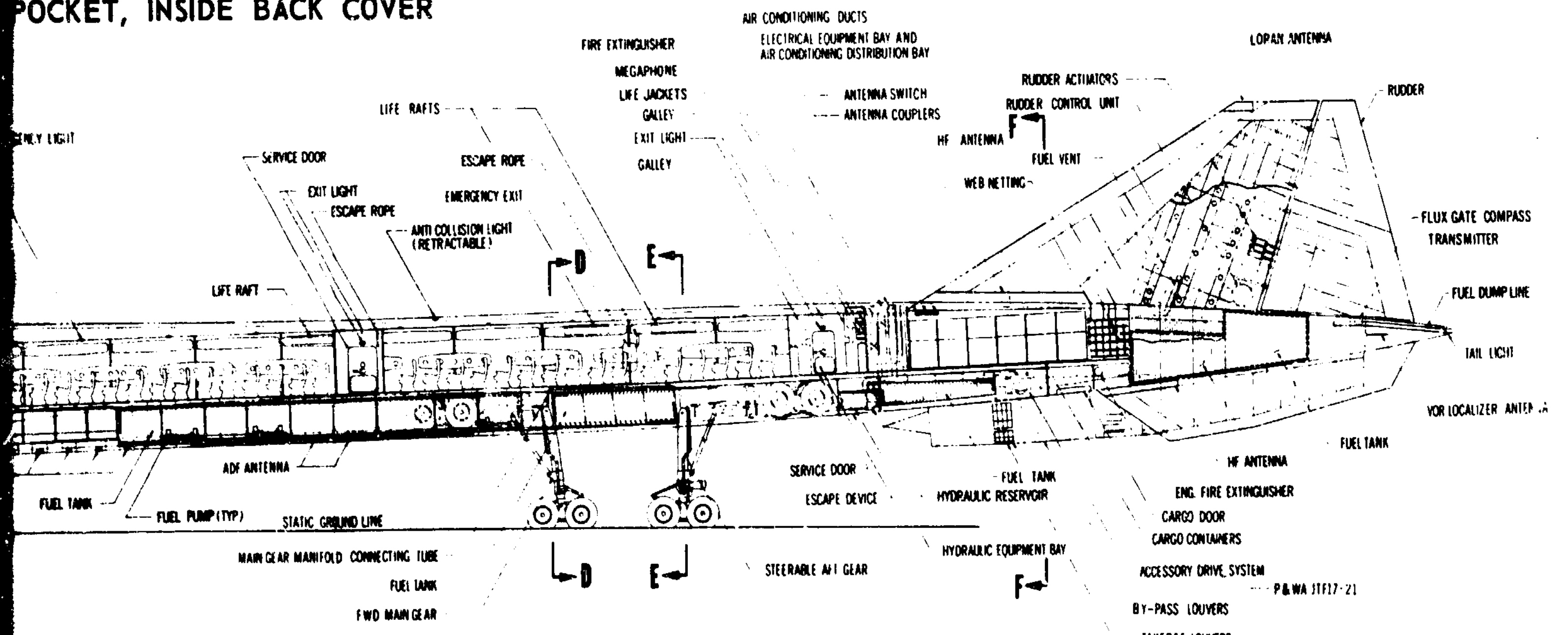

Figure 3-4. Inboard Profile (P&WA)

3.1 PASSENGER AND CARGO PROVISIONS

A spacious interior 189-ft long with a nominal interior width varying from 139 in. to 177 in. has been provided (Fig. 3-5). The triple seats used for 6-abreast seating are 63-in. wide, several in. wider than on current jet transports. Aisles are maintained at 18 in. and better. At entries and associated service cores, wider areas are maintained. Floor-to-ceiling height is nominally 83 in. The location of fixed or semi-fixed cabin features such as doors, windows, lavatories and galleys, permits a wide variety of efficient seating configurations. The 277 passenger international mixed configuration is shown in Fig. 3-6.

The first class section accommodates 30 first-class passengers at 40-in. seat pitch in 4-abreast seating. The tourist section provides 6-abreast seating for 247 passengers at 34-in. seat pitch.

	B-2707	707-320B
PASSENGERS		
International (10% F.C./90% T.C.)	277	163
All Tourist	298	189
VOLUME PER PASSENGER (FT^3/PASS.)		
International	70.1	56.0
All Tourist	65.2	48.3
CARGO VOLUME (FT^3)	3106	1775

Figure 3-5. Passenger and Cargo Volume

The all-tourist international configuration is shown in Fig. 3-7. Seating is provided for 298 passengers at 34-in. pitch. Conversion of the cabin interior to this all-tourist configuration from the 277 passenger international mixed configuration is easily accomplished.

The design is well adapted to requirements for servicing the cabin interior, providing for safety of the passengers, and permitting easy conversion of the interior to varying airline requirements. The simple symmetry assures an easily understood and remembered evacuation plan. The 42-in. wide main entry doors, enhance the opportunity for rapid, uniform flow of passengers. Tests indicate an evacuation time of less than 90 sec for 277 passengers with the exits blocked on one side (see Fig. 3-8). A complete ditching operation can be accomplished in less than 4 min for 277 passengers with half the exits blocked.

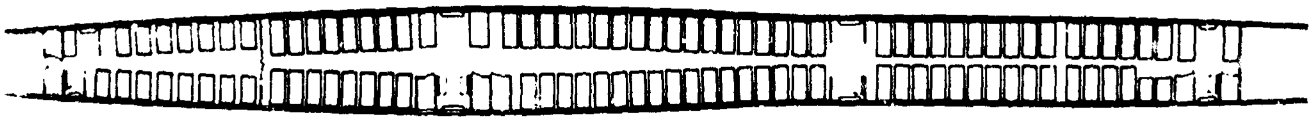

Figure 3-6. 277 Passenger International Mixed

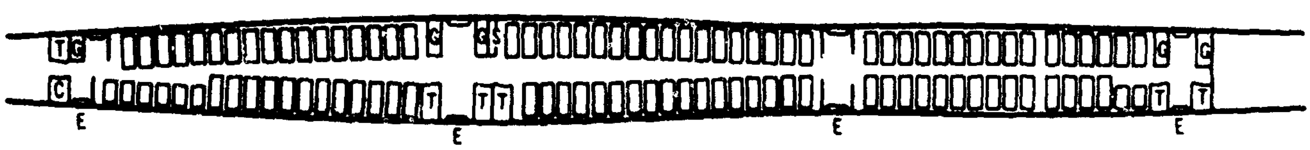

Figure 3-7. 298 Passenger International Tourist

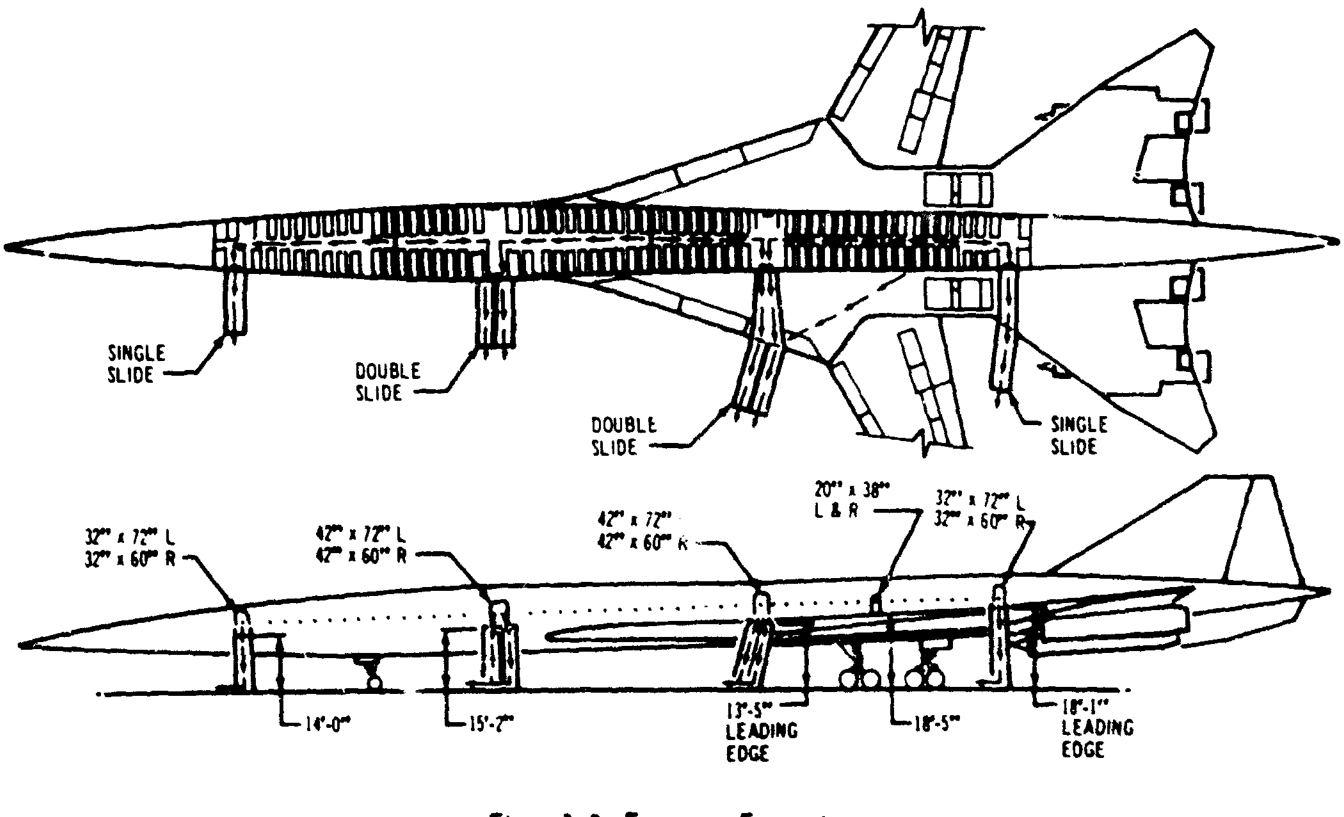

Figure 3-8. Emergency Evacuation

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The cargo accommodations concept is shown on Fig. 3-9.

A comprehensive discussion of passenger and cargo accommodations is contained in Systems Report - Part B, V2-B2707-11.

giving high strength efficiency for basic panel loading. Main frames and bulkheads are provided at points of load concentration. Close stringer spacing provides the required aerodynamic smoothness under flight loads and temperatures. A fuselage cross section at a typical frame is shown in Fig. 3-11.

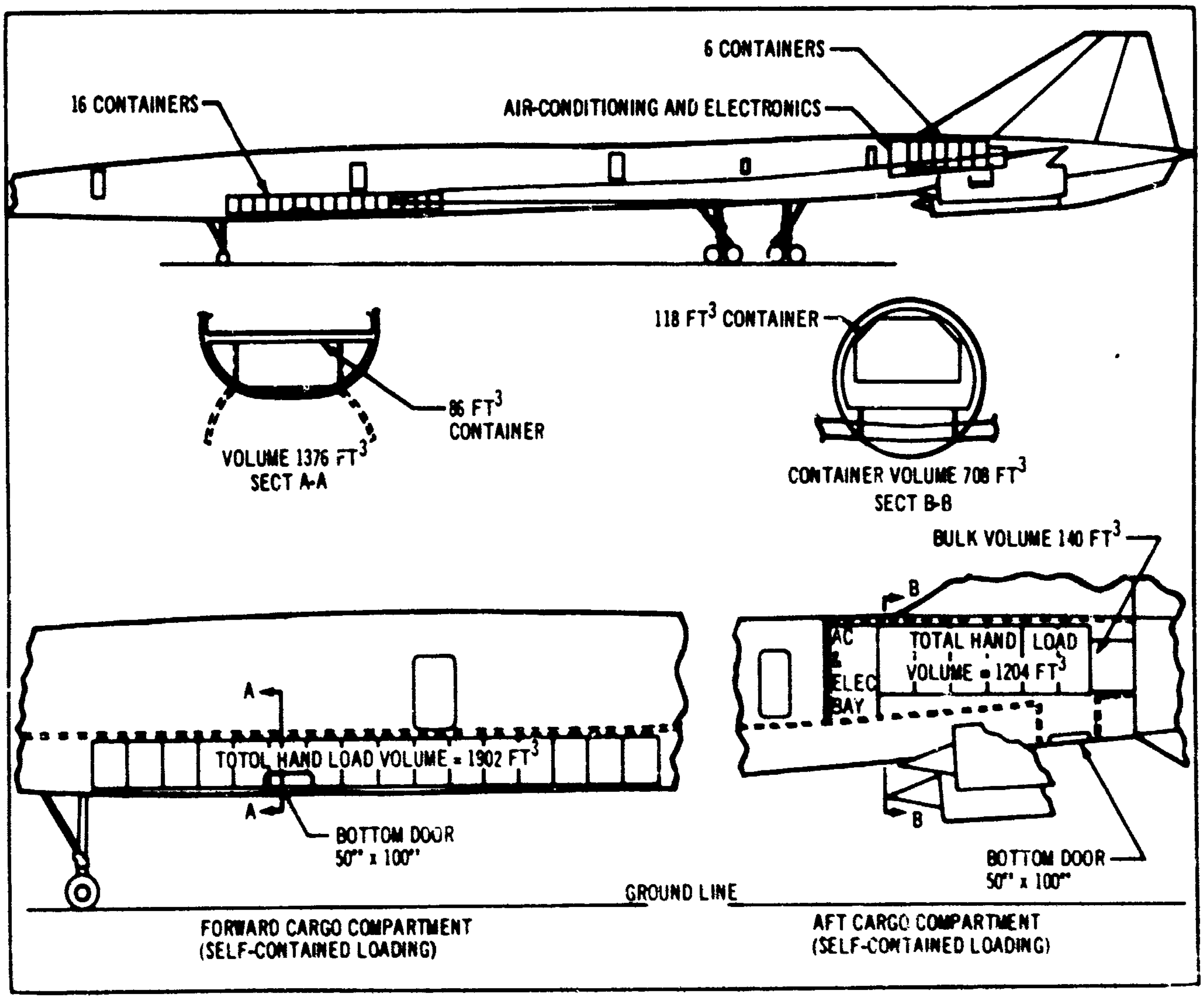


Figure 3-9. Cargo Accommodations

3.2 FUSELAGE

The titanium alloy fuselage shell is of conventional semi-monocoque skin stringer construction stabilized by ring frames. See Fig. 3-10. It is the same type of construction used on the 707, 727 commercial airplanes and provides ease of fabrication, inspection, and repair, as well as Chem-milling provides pad-up for skins, ensuring structural adequacy of fatigue-critical joints. Completion of the development of diffusion bonding and high temperature adhesive bonding will provide alternate methods of skin pad-up. Tearstopper straps are riveted. Their location is determined by the relationship of skin thickness,

fuselage radius, and skin heat treat condition. Most skins are tapered in thickness for weight saving. Skins are reinforced around cutouts and edges by chem-mill sculpturing.

Stringers are formed hat or zee sections tapered in thickness for weight optimization. Stringer ends at tension fatigue critical splices have bonded reinforcements or are padded up by chem-milling. In tension fatigue critical areas the skins and stiffeners are fastened with titanium rivets using an improved fatigue-resistant rivet installation technique.

The aft section of the forebody pivots about a point aft of the flight deck windows and is actuated by an electromechanical screw. The forward section of the forebody is articulated about a second pivot point forward of the forebody windows to maintain alignment of the weather radar and pitot probe during forebody actuation and to provide a suitable ground clearance for runway and taxiway markers or snow bank accumulations.

Portions of the floor area in the cargo and passenger compartment are readily removable to provide access to control cable installations.

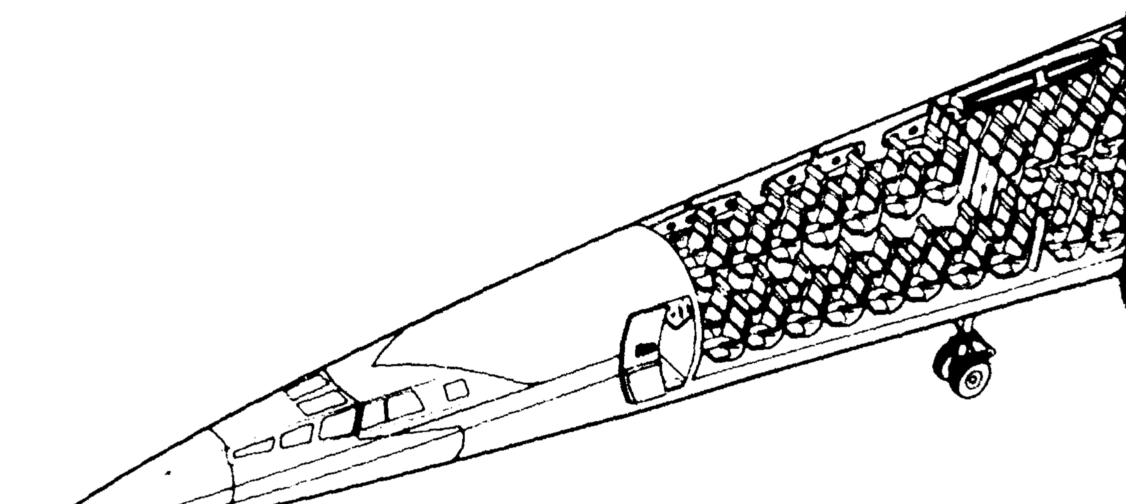
Four passenger doors, four service doors, four emergency exit hatches, and two cargo compartment doors are provided in the airplane. The size and location of these doors is shown previously in Fig. 3-8. All of the doors are advanced derivations of the same door types proven in Model 707/727 service. They combine the structural, mechanical, and seal features which have proven serviceability and effectiveness with modifications required to serve high temperature and high pressure.

An overhead and left-hand side hatch are provided in the flight deck for emergency exit. Access to the lower lobe system installations is provided by removable panels in the flight deck floor and exterior access panels.

The 6 1/2-in. diameter passenger windows, at a nominal 20-in. spacing, in groups of five, employ two separate panes to minimize heat transfer into the cabin and provide dual-load path reliability for the pressurized compartment.

The windshields are plug-type, designed to withstand three factors pressure on the primary laminated windshield. The three chemically strengthened glass panes provide three separate fail-safe paths capable of one and one-half factors pressure each. The laminated windows are designed to utilize the best possible interlayer material for each application. An interlayer material being evaluated for the side windows is a cast-in-place material superior to currently available interlayer materials for higher temperature applications. The interlayer for the forward windshield is polyvinyl butyraldehyde (P. V. B) used in subsonic aircraft. This materials provides the best shock attenuation required for "bird proofing" the windshields.

The windows are coated with vacuum deposited gold film, for low infrared emittance and except for the windshield are unheated. The air gap between the outer panel and the laminated panel is vented by a closed system to ambient pressure. The coatings are used principally to reduce heat transmission except for the forward windshield where it is also utilized for deicing.



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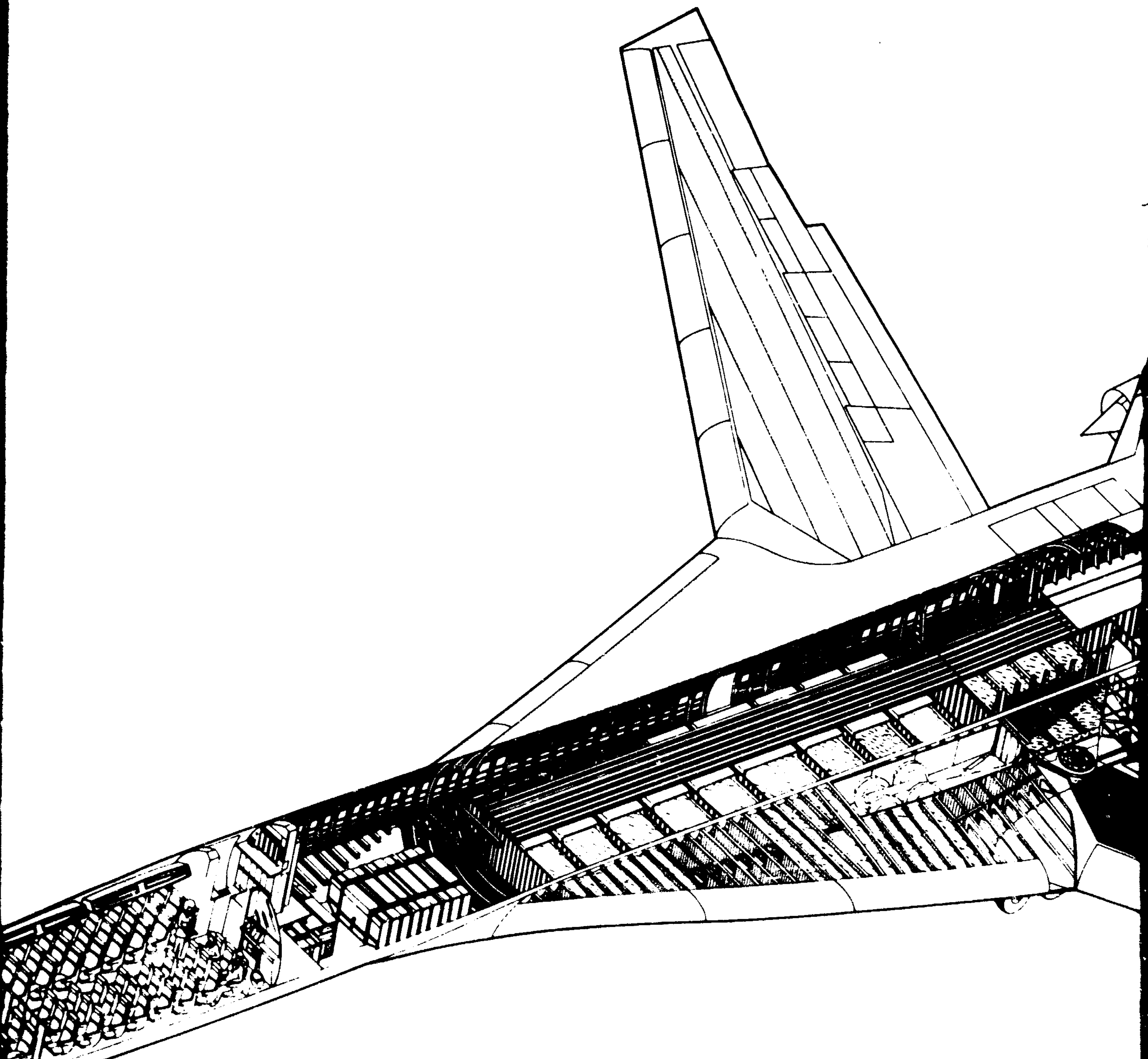

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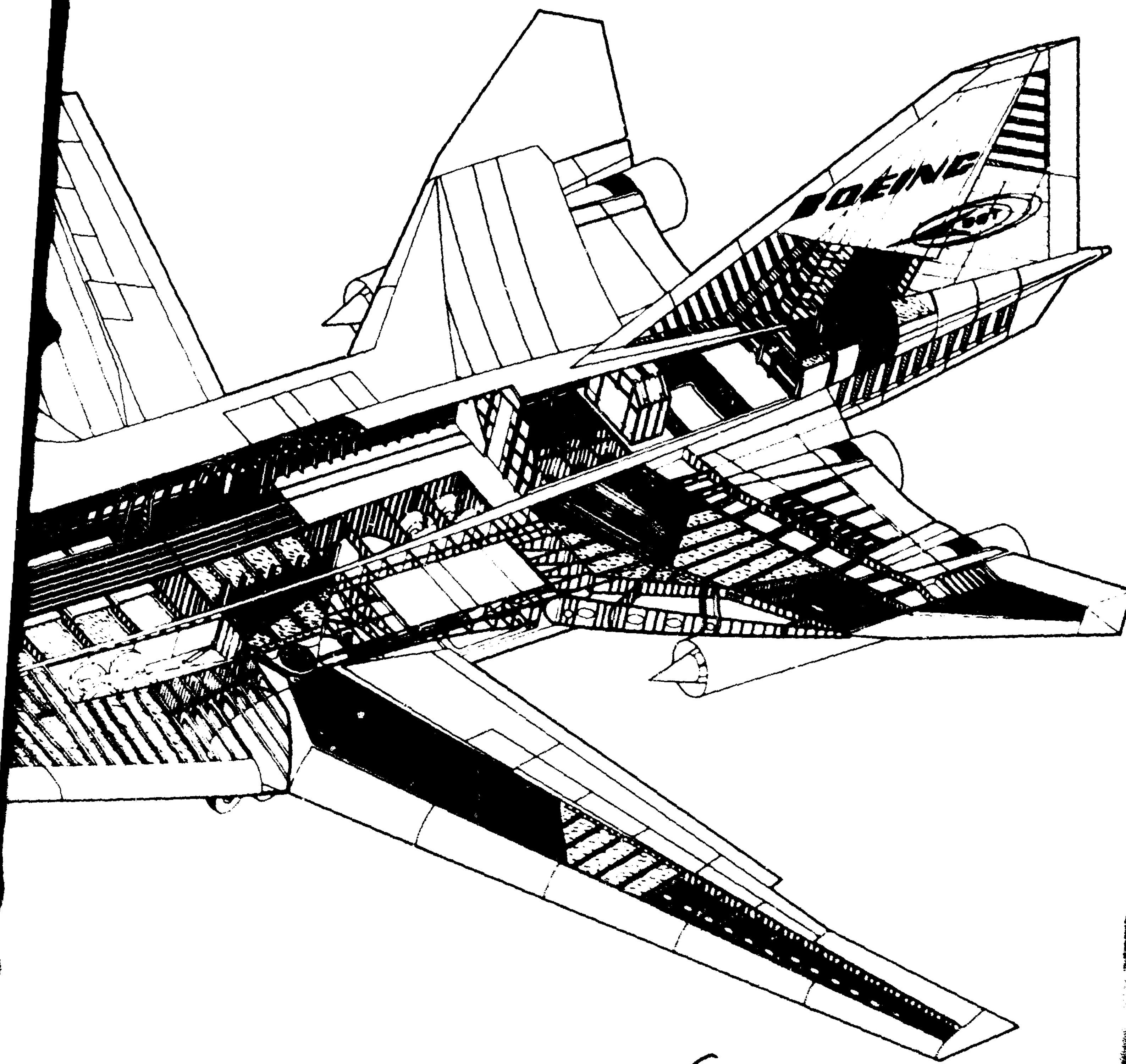


Figure 3–10. B–2707 Structures

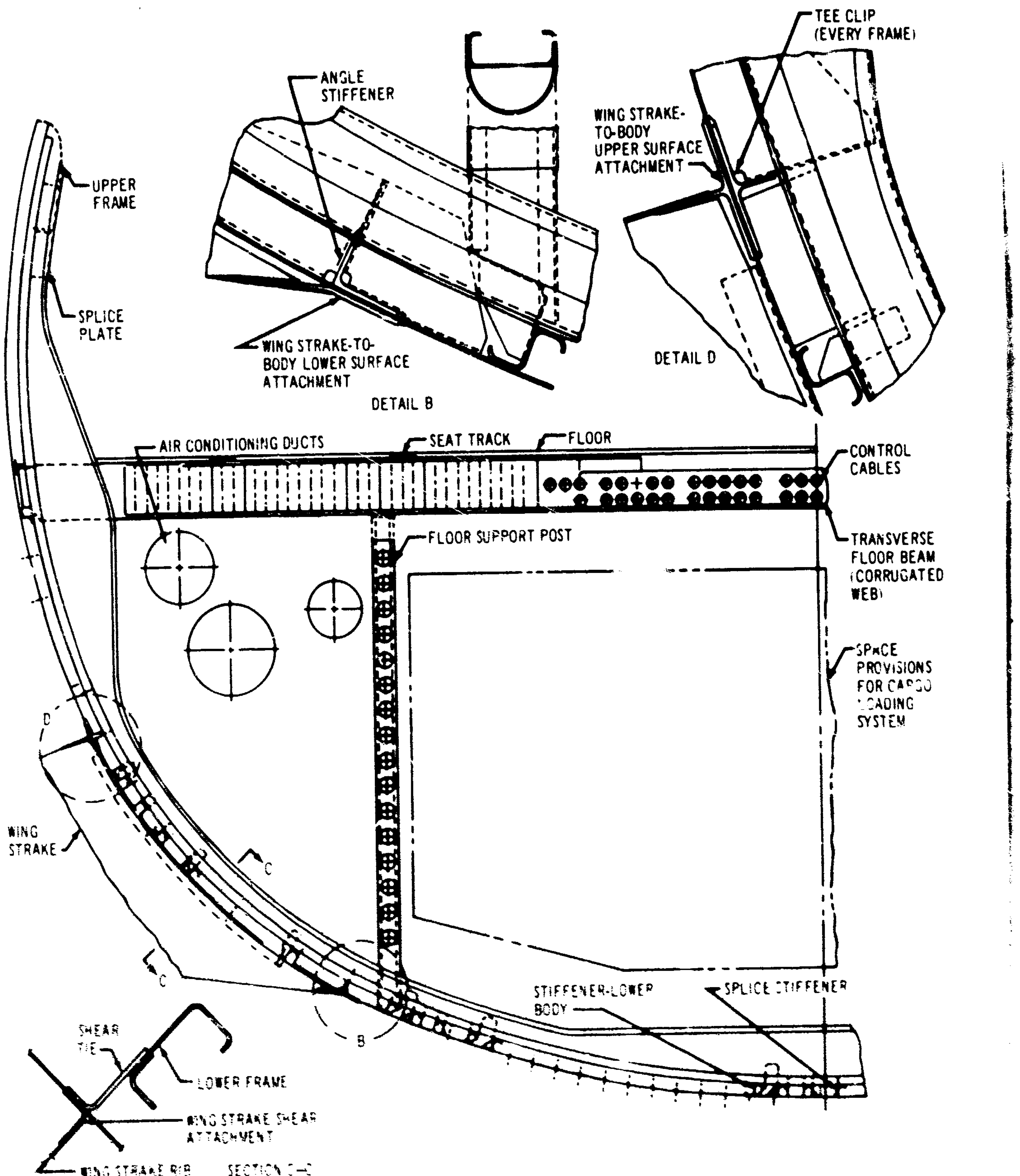


Figure 3-11. Typical Body Rib Section

3 WING

ıe B-2707 wing is a carefully optimized structure ıcorporating aerodynamic camber and twist. The ıng is pivoted at approximately 29 percent of the ımi-span (wings aft). For landing, and takeoff, e wings are positioned to a leading edge sweep of) degrees. In this position, the high performance ailing edge flaps and leading edge slats are ex- nded (Fig. 3-12A). For subsonic cruise with the leading edge of the wing swept to 42 degrees, the leading edge slats are retracted and the trailing edge flaps are positioned to form an aerodynamically efficient trailing edge closure (see Fig. 3-12B). For subsonic and supersonic cruise with the wings swept to 72 degrees, the flaps and slats are retracted. The flaps are positioned to provide aerodynamic gap closure between the wing and the horizontal tail (see Fig. 3-12C).

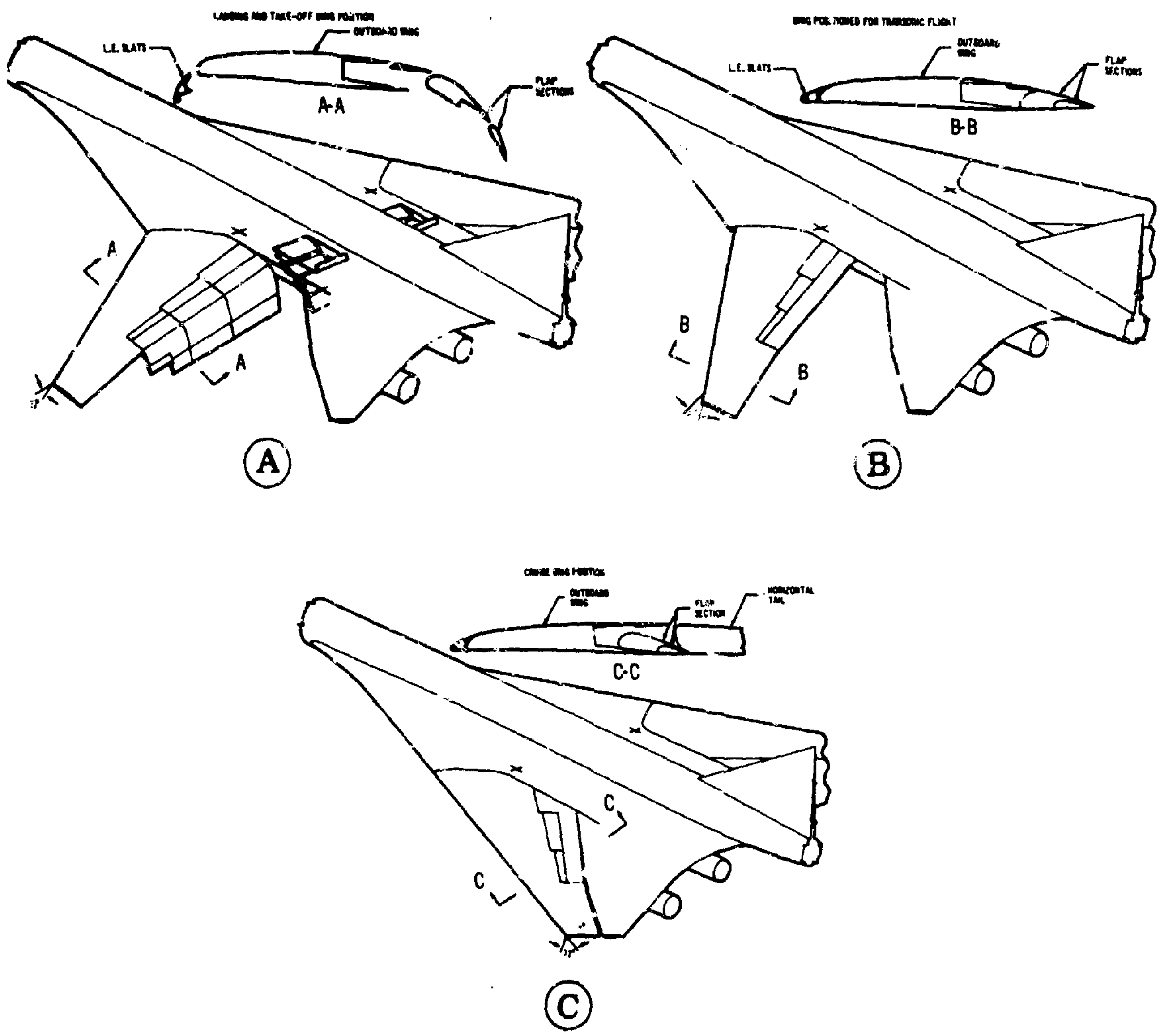


Figure 3-12. Outboard Flap Detail

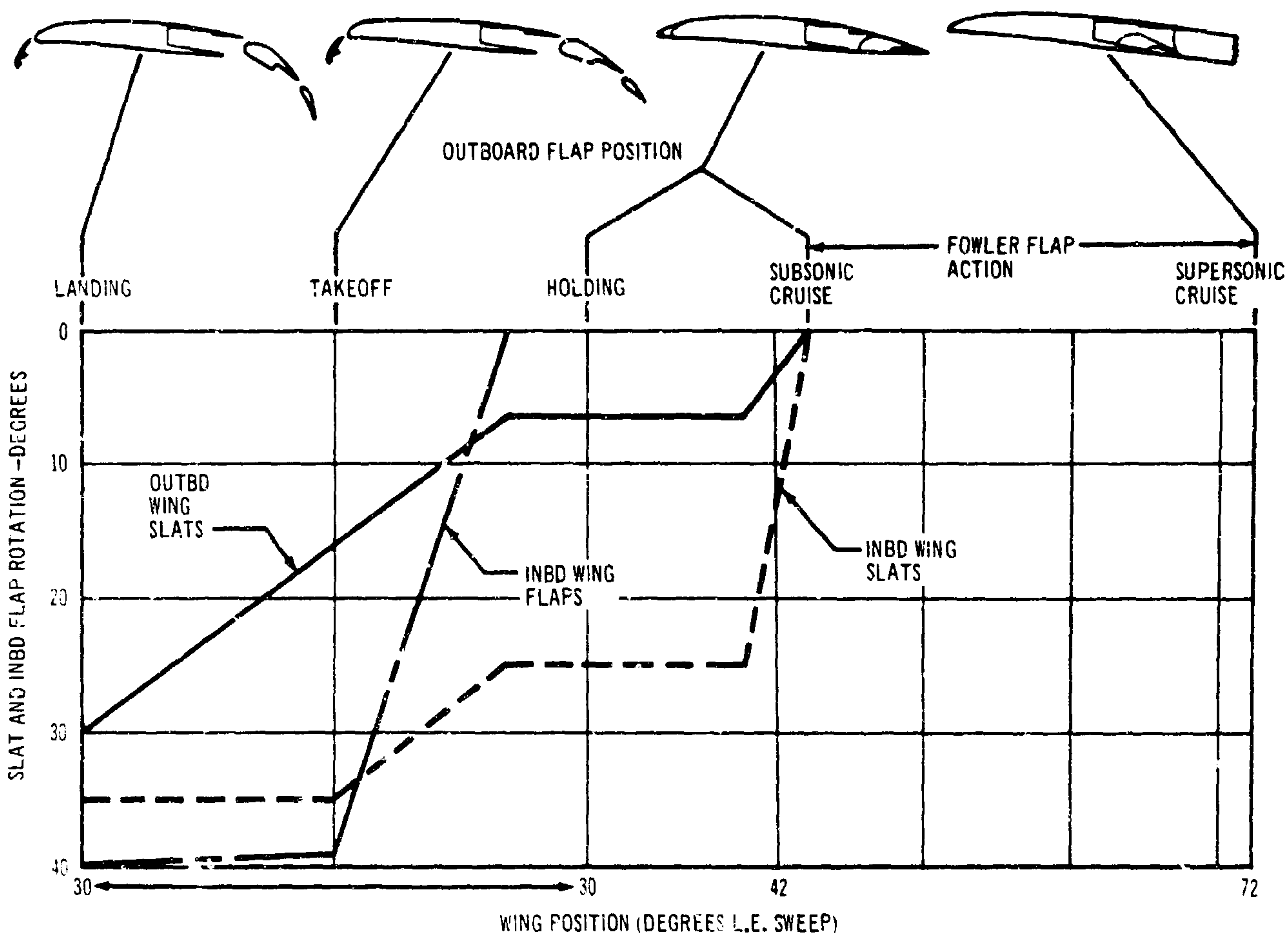


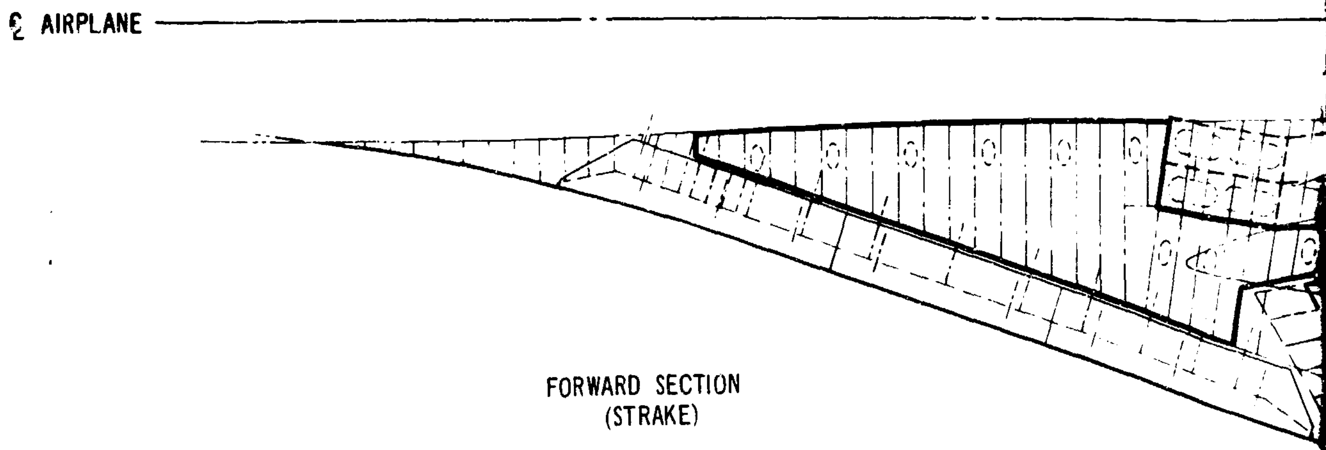
Figure 3-13. Slat and Flap Programming

A schedule showing slat and flap positions as a function of wing sweep is shown in Fig. 3-13. Fig. 3-14 shows the structural arrangement of the wing. The major segments of the wing consist of:

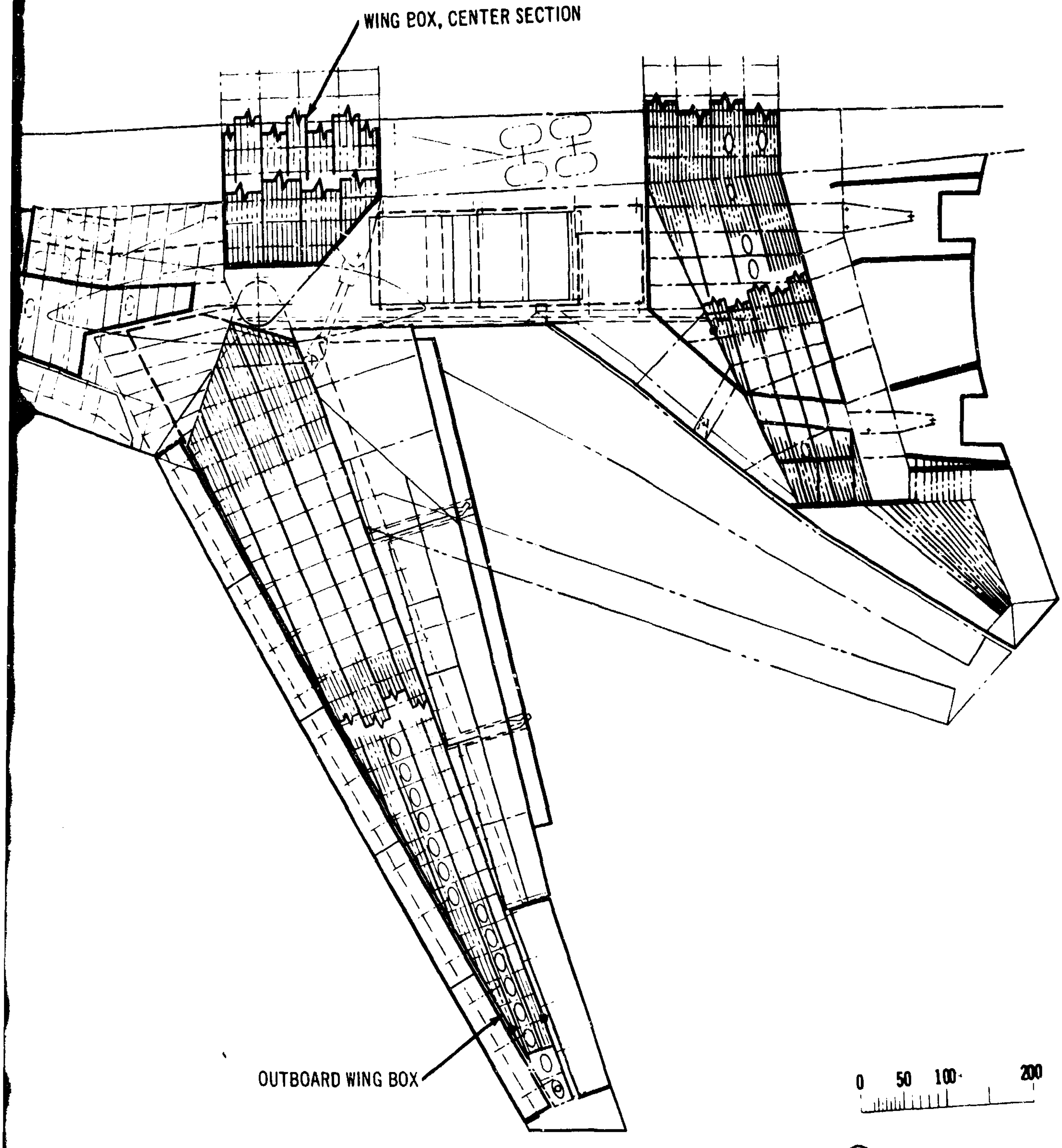
- The movable outboard section
- One center section box, inboard of the pivot, extending through the fuselage
- An inboard leading edge (strake) section located forward of the above section.

The primary wing bending structure for the outboard wing and main wing box is conventional skin-stringer titanium, using two wing spars. The area between the spars on the outboard wings serves as an integral fuel tank. A special lightweight insulation material is added to the lower surface of the fuel tank.

Forward of the wing front spar, the fixed leading edge structure of the outboard wing is fabricated of both light gage sheet and honeycomb construction. Spoilers, trailing edge flaps, and an aileron occupy the area aft of the rear spar. The spoilers are simple built-up honeycomb structures with ribs and machined spars, hinged from support fittings attached to the rear spar. The honeycomb upper surface trailing edge panels, aft of the spoilers, are actuated to be compatible with flap position and wing sweep such as to give a faired upper surface airfoil in the subsonic high speed, intermediate sweep, flight condition. See Fig. 3-14.



A



B

Figure 3-14. Structure Diagram, Wing and Horizontal Tail

Three double-segmented, double-slotted, trailing edge flaps are installed on the outboard wing. (See Fig. 3-12.) The aft segment is movable, relative to the main section, and moves on high heat-treated steel tracks. Actuation is accomplished by picking up the motion of the main flap screws. The forward segment of each main flap is supported by three high-heat-treated steel tracks which cantilever from the rear spar. Each main segment is actuated by two screw actuators. Flap segments are constructed of light gage honeycomb panel structures and extruded, machined, longitudinal members assembled with titanium fasteners. Fixed areas of the wing trailing edge structure and the aileron are fabricated of light gage honeycomb construction.

The basic wing box is permanently attached to the fuselage by forged fittings attached at the front and rear spar.

The outboard main landing gear is attached to the front spar of the wing at two trunnion bearings near the wing pivot. Loads are distributed into the primary wing box structure through forgings and rib assemblies. The inboard main gear is attached to the wing rear spar in a similar manner. (See Fig. 3-15.)

The wing strake structural assembly is built up primarily of light gage honeycomb construction surfaces, supported by ribs of corrugated web design. The front spar is a built up web-stiffener conventional design. The attachment of the strake to the fuselage is made at the matching body frame locations. The aft connection is made along the front spar of the wing box.

The strake fuel tank is of integral construction. The honeycomb surface structure serves as an excellent fuel tank heat insulation material.

The wing pivot screw actuator support structure is mounted to the rear spar of the outboard and inboard wings. The major portion of the structure is composed of forgings and weldments. Dual load path fail-safe provisions are incorporated in the design. Failure of any single component will not lead to complete loss of the screw support.

Wing bending loads through the wing pivot are carried by an upper- and lower-journal bearing assembly as shown in Fig. 3-16. Control system and fuel lines are routed through the pivot centerline.

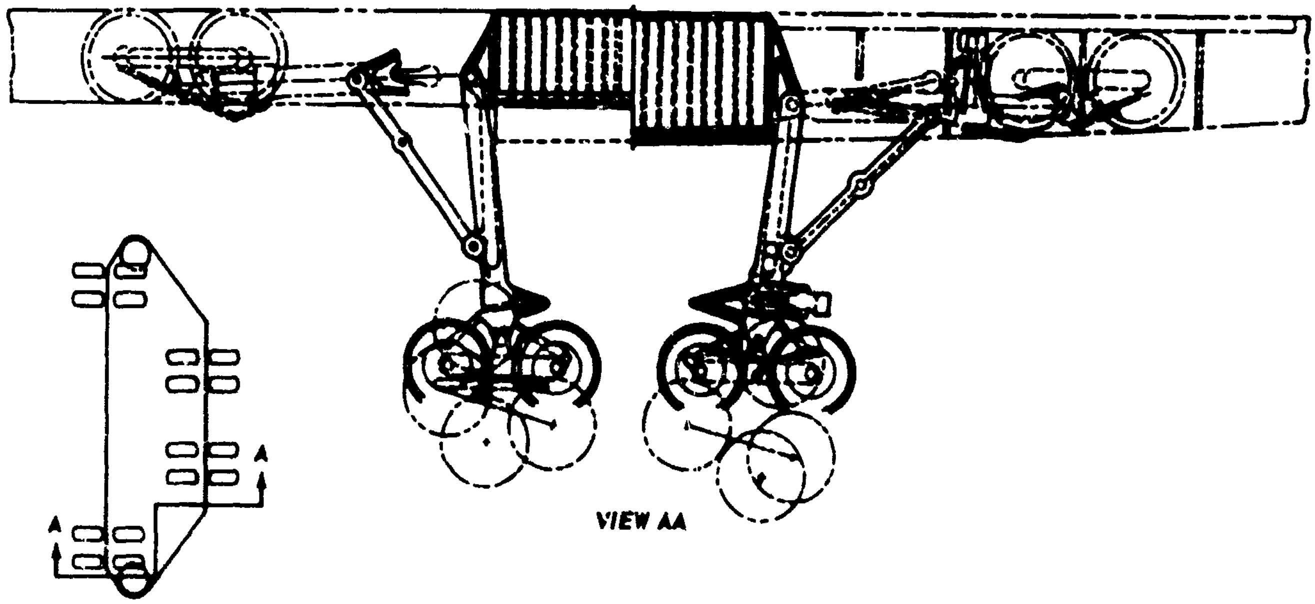


Figure 3-15. Main Landing Gear Structure

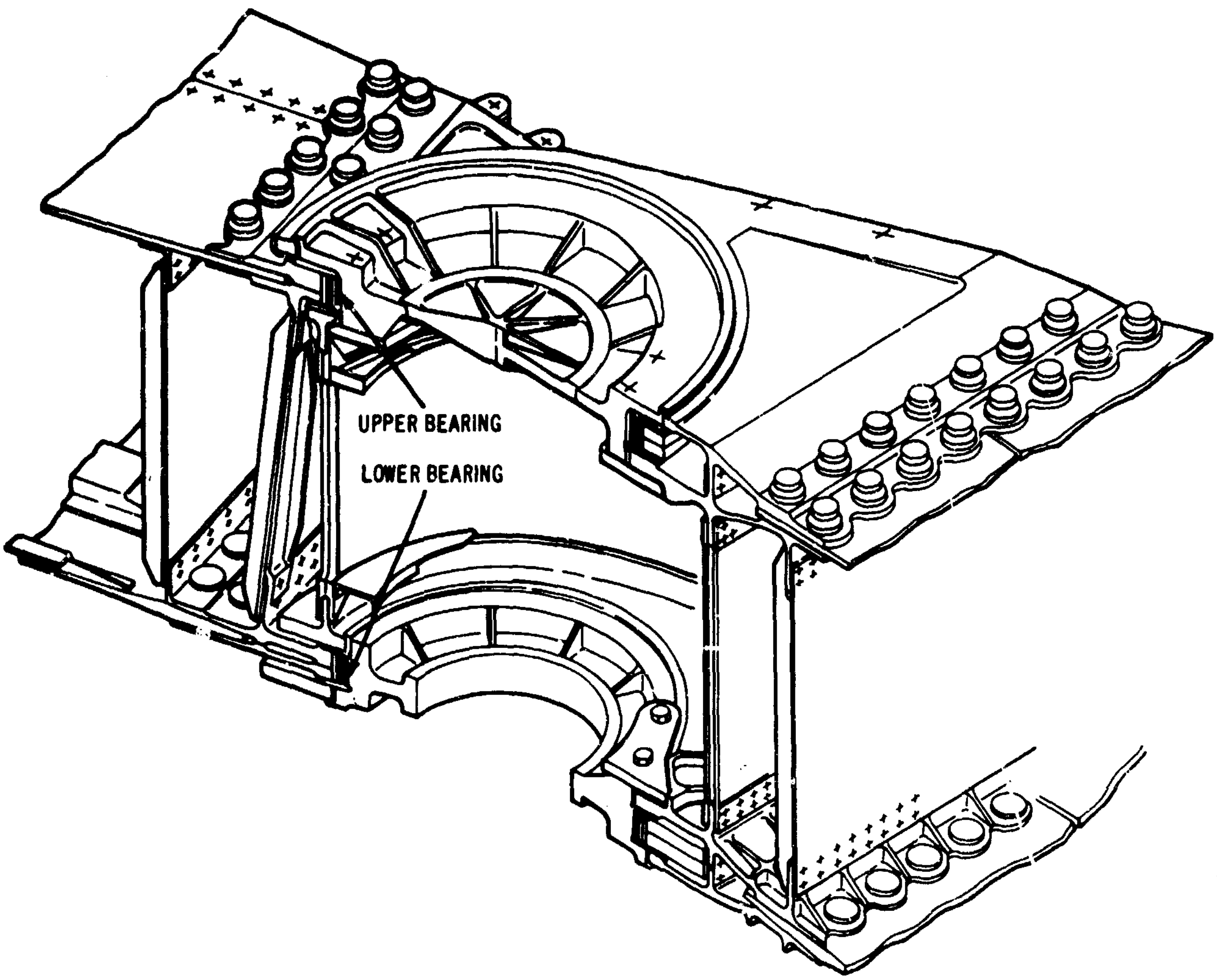


Figure 3-16. Wing Pivot

Additional information relative to wing pivot design and test is contained in Structural Test, V2-B2707-9 and Airframe Design Report V2-B2707-6.

3.4 EMPENNAGE
The general arrangement of the titanium stabilizer structure is shown in Fig. 3-17.

The structure of the primary box closely resembles Boeing subsonic wing type construction. The leading edge is constructed of corrugated ribs covered by honeycomb panels. Ribs are spaced to provide bays for an accessory drive system, and environmental control system components.

Access openings are provided to each bay as shown in Fig. 3-18. Space is provided for systems routing through the leading edge cavity and into the body.

Two wing-to-stabilizer shear connection fittings are provided as shown in Fig. 3-19. Loads from these fittings are transferred through the ribs to the structural box. Engine support is provided by fittings attached to the structural box.

The inboard elevator is located between the engine pods and the auxiliary elevators are located above the engine pods. Hinge and actuator fittings are supported by the elevator spar. Actuation is by

multiple hydraulic actuators with the actuator and hinge loads reacted by the stabilizer box.

The outboard elevon is supported by bearings in forged support fittings attached to the rear spar of the stabilizer and hydraulic actuator loads are reacted near the center of the box on forged attachment fittings.

The vertical fin structural box has skin stringer cover panels, mechanically assembled, and supported on ribs and spars. Ribs are corrugated welded construction to provide minimum weight. Spars utilize both corrugated construction and stiffened web construction. Honeycomb panels form the covering for the leading edge structure. A segmented rudder is provided with hydraulic actuation on the lower segment. The lower segment mechanically actuates the upper segment.

Ventral fin structure consists of honeycomb panels supported on corrugated ribs. The lower edge is segmented and readily replaceable.

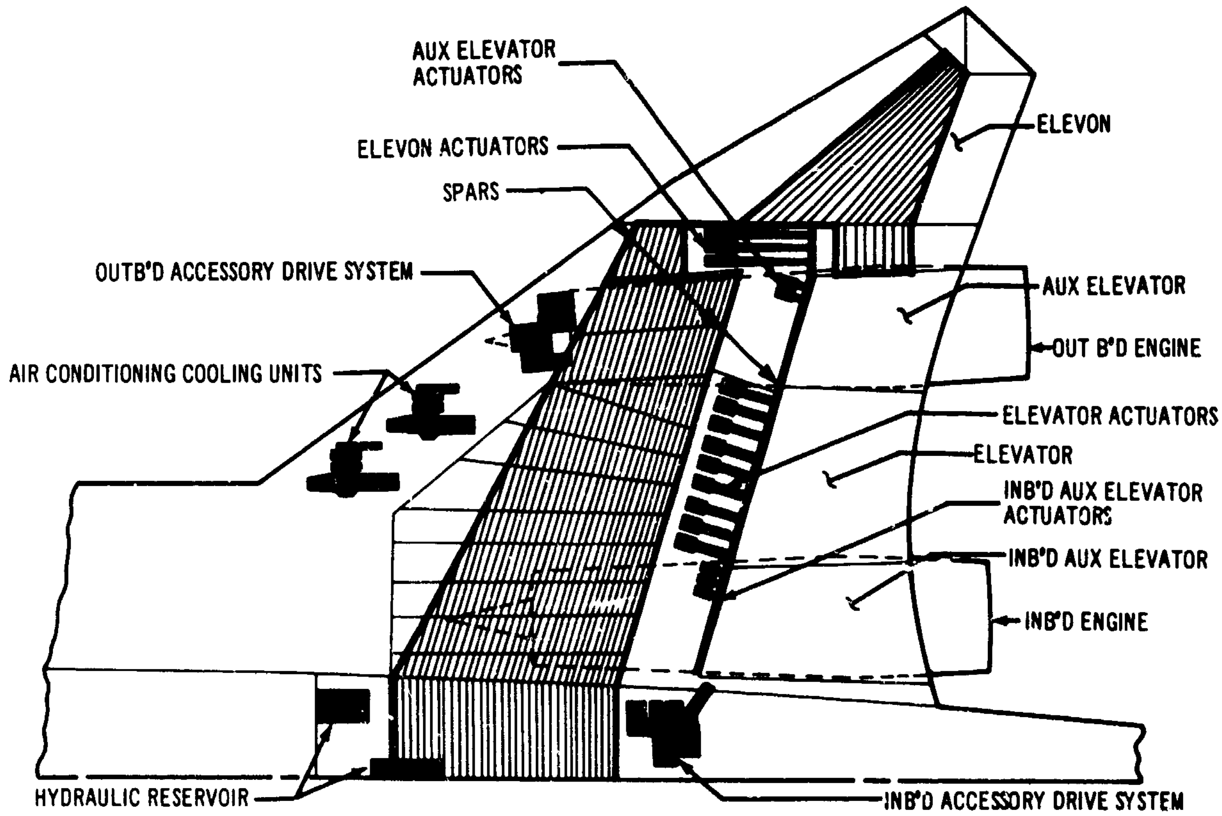


Figure 3-17. Horizontal Stabilizer

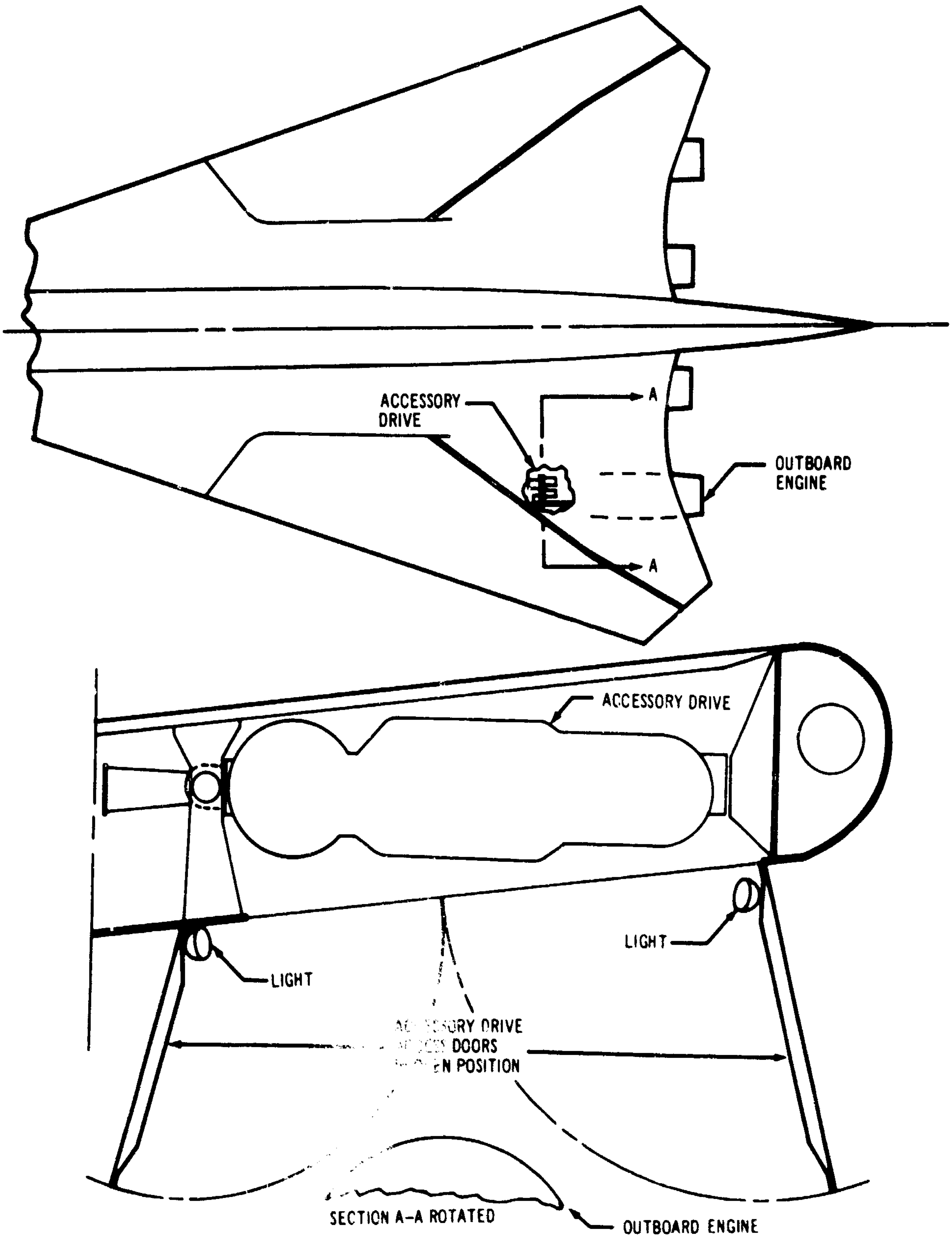


Figure 3–18. Accessory Drive Installation and Access

V2-B2707-1

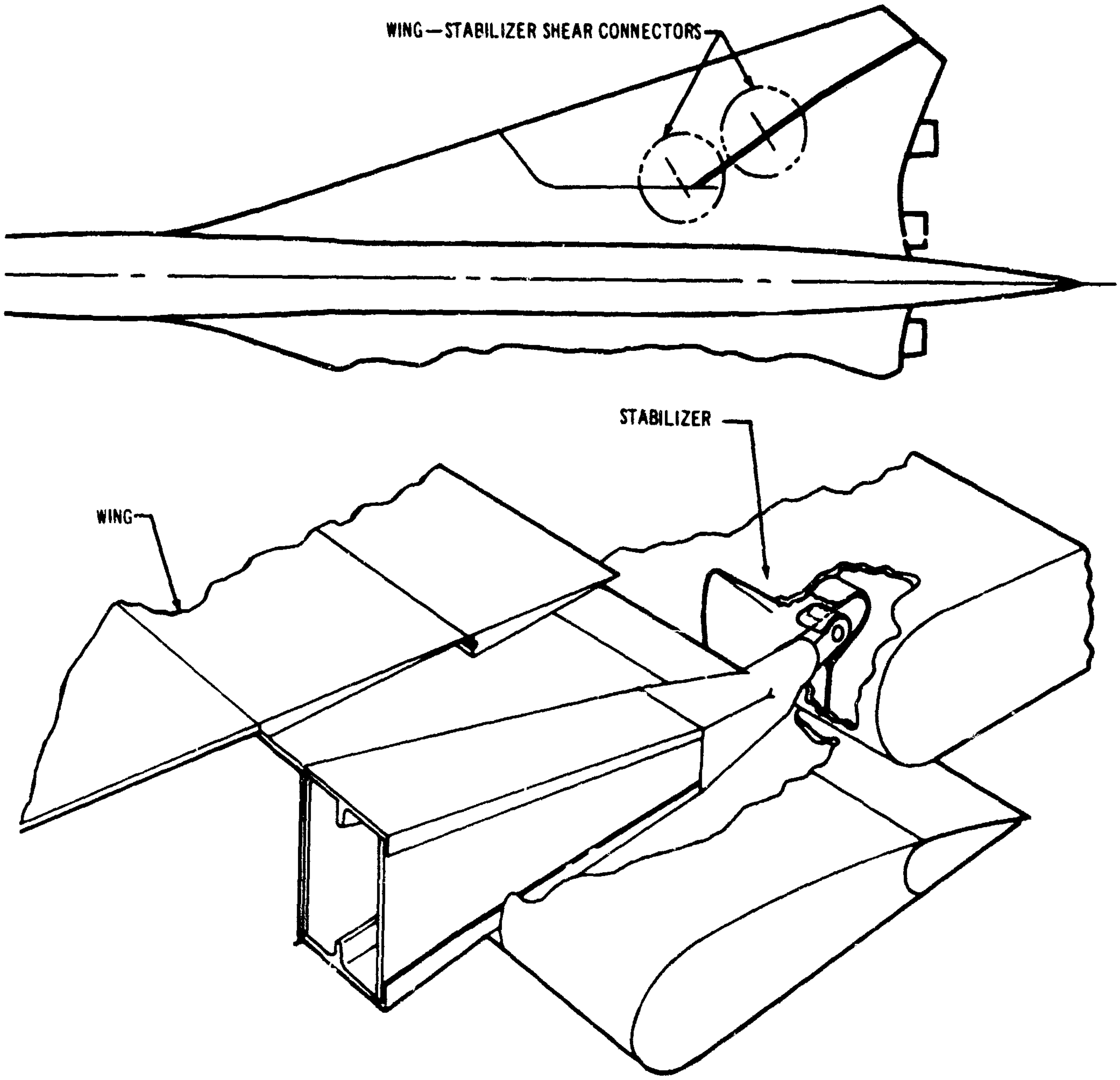


Figure 3-19. Typical Wing-Stabilizer Shear Connector

3.5 LANDING GEAR

The main gear design (see Figs. 3-20 and 3-21) consists of four 4-wheel trucks, each truck similar in size and design to those used on the 707-320 airplane. A long stroke oleo is used on the aft gear to provide a soft landing characteristic. A manifold system assures equal loads on each main gear for uneven runway conditions. The relationship of the gear to the center of gravity for all flight weight conditions provides adequate steering loads on the conventional nose gear, Fig. 3-22. The aft main gears incorporate a proportional steering system to permit a minimum turning radius of 162.5 feet without undue stress on tires or gear.

Wheel brakes are disc-type and hydraulically actuated, and are equipped with automatic adjusters for brake wear. The normal wheel brake

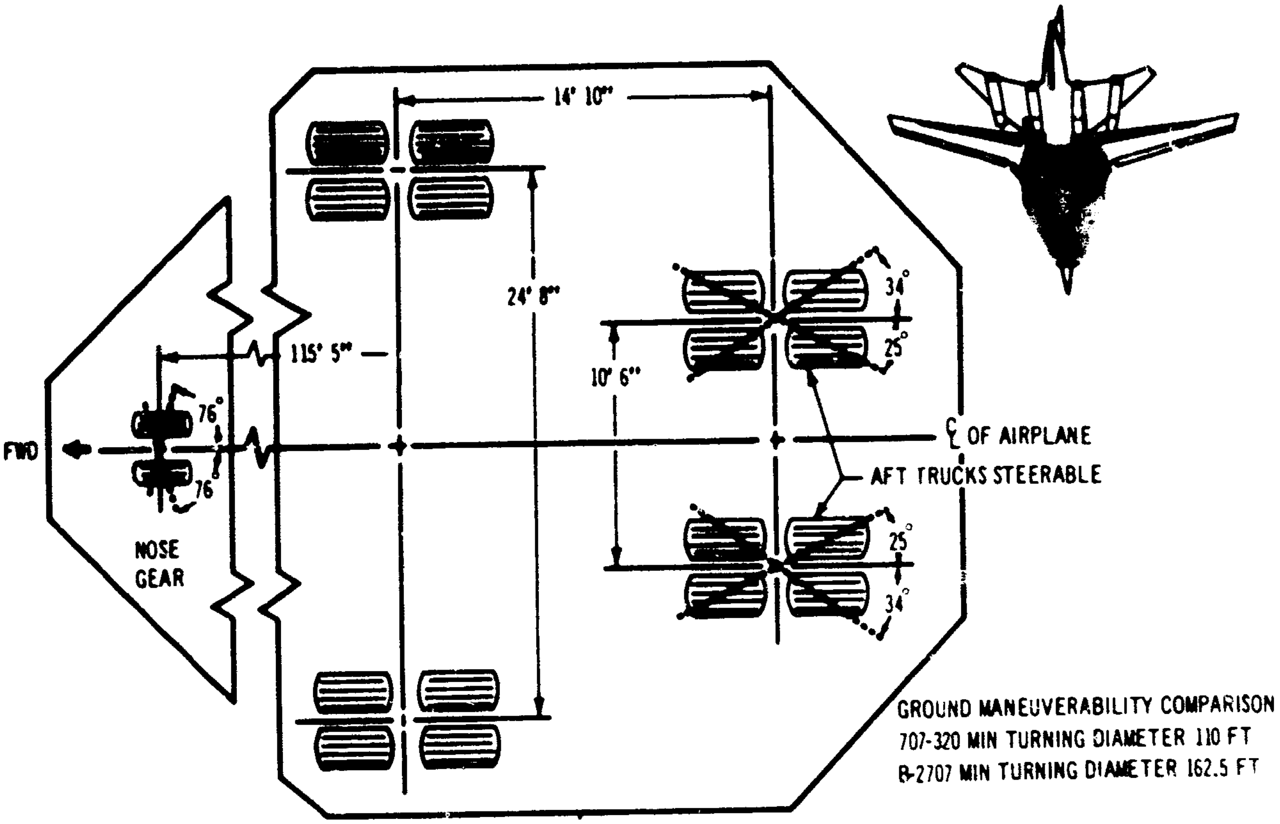


Figure 3-20. B-2707 Landing Gear

system pressure is supplied by one of the hydraulic systems with an electric pump standby. A modulated antiskid system with individual wheel control is provided on all main brakes. The antiskid braking is available with normal and standby hydraulic systems.

The four main landing gears are stowed in a manner that minimizes their interference with passenger, cargo and fuel space. The two forward main gears are attached to the center wing box outside of the body, and retract forward into the inboard wing. The two aft main gears are attached to the wing center box within the body, retract aft, and stow under the passenger floor.

Each of the five wheel wells is covered by four doors, - two wheel doors and two strut doors. The wheel doors are operated hydraulically; they open before gear extension and close again when the gear is fully extended. The strut doors are mechanically linked to the gear and remain open while the gear is down.

The actuators are conventional linear hydraulic actuators. The locks are positive over-center mechanical devices which remain secure in the event of hydraulic system failure. Proper sequencing is assured by direct mechanical linkage from each lock element to the appropriate hydraulic sequencing valve so that each individual step of the sequence must be complete with the corresponding lock properly engaged before the next step can be initiated. The system is capable of being reversed at any point in the normal landing gear extension or retraction cycle while maintaining sequence.

If basic hydraulic power is not available, a standby landing gear extension system using an independent hydraulic power supply is provided to unlock the doors, unlock the gear up-locks, and, where needed, drive the gears into the down and locked position.

The nose gear and each main gear are provided with fore and aft towbar fittings so that the airplane can be pulled or pushed either forward or backward by a tractor coupled to any one gear. For a three percent grade, 50,000 lbs tractive effort is required.

The main gears, essentially the same in loading and design as that of existing 707-320's, can be jacked employing 35 to 40-ton "alligator" jacks now in use by airlines.

Should ultimate gear design loads be exceeded during landing, fused links in the drag struts will separate, allowing the gears to fold essentially aft about their normal trunnion axes. Failure of the attachment point will allow the primary wing structure containing fuel to remain intact during the operational emergency.

Spark ignition hazard in the event of an emergency landing due to main gear malfunction is virtually nonexistent because spark generation is centralized at the ventral fin, well below the fuel vent outlet located on the vertical tail. In the event of nose gear failure spark ignition is limited to the nose of the airplane. The nose is well forward of any fuel containment areas, and fire hazard from spark ignition is expected to be extremely remote.

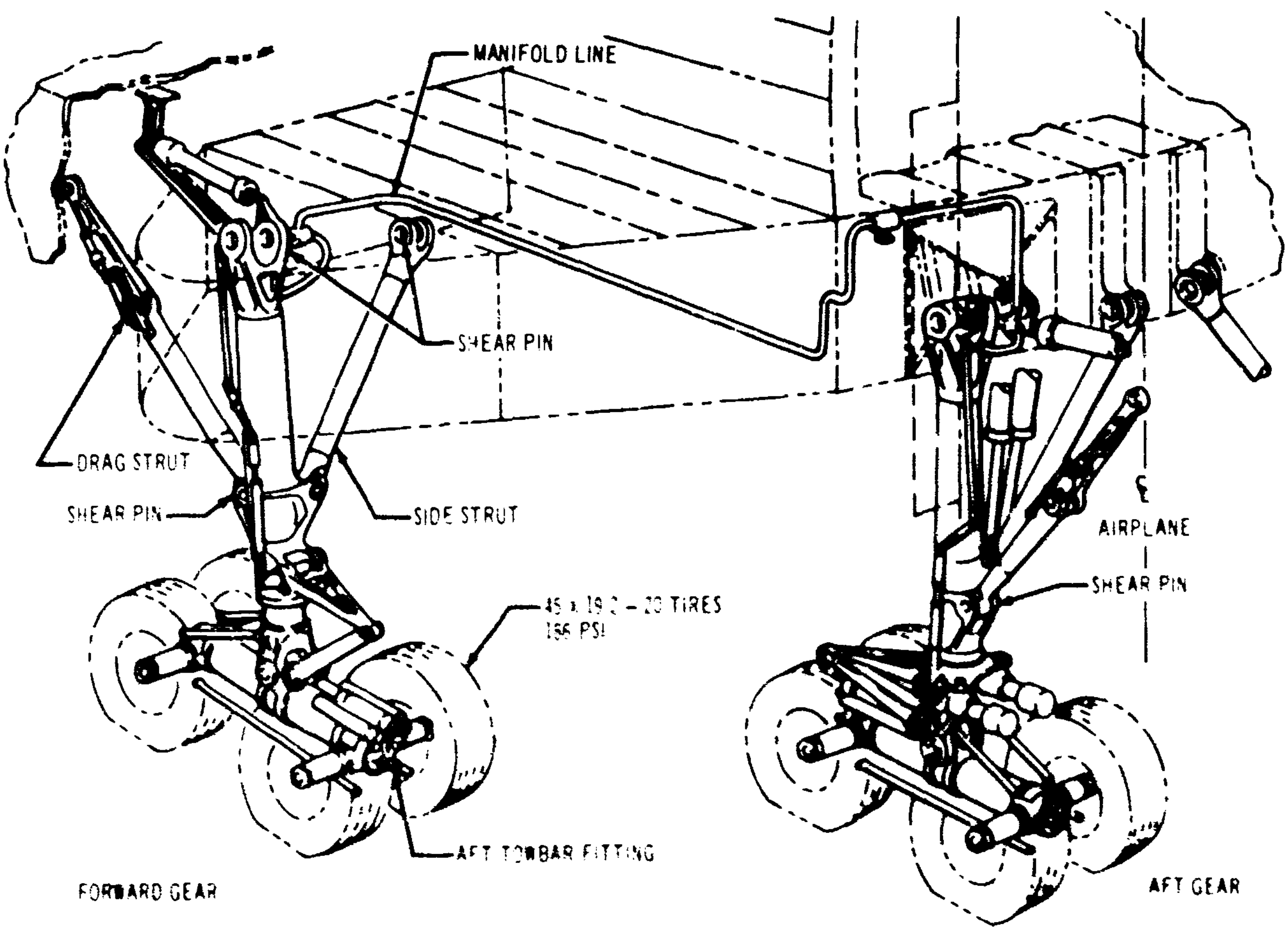


Figure 3-21. Main Gear

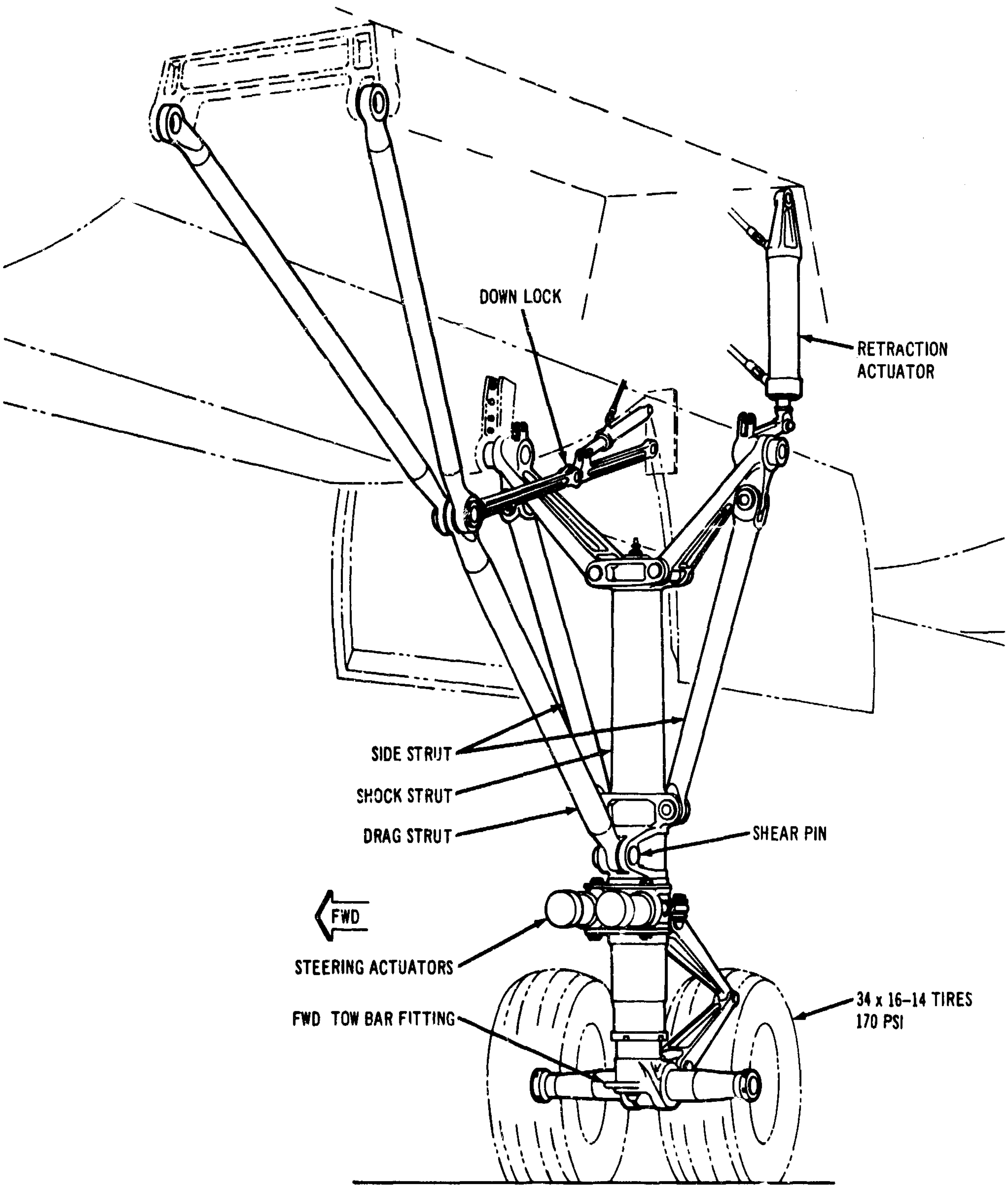


Figure 3-22 Nose Gear

3.6 FLIGHT DECK

The flight deck, Fig. 3-23 is arranged for a 3-man crew operation. Two observer stations are located behind the captain's seat.

The flight crew has been given excellent visibility in the subsonic flight regime by the use of a pivoting nose, Fig. 3-24. Supersonic vision with the pivoting nose in the UP position meets the requirements of visual horizontal reference. Adequate forward vision is provided to aid in overtaking situations and in weather (cloud) recognition.

The crew arrangement permits good communication between crew members, via voice or by touch without dependence on interphones.

All crew members' seats are powered to move fore and aft as well as vertically. The flight engineer's seat travel allows him to move slightly behind and between the captain and first officer, and at the same eye level for monitoring the pilot's panel as well as acting as another observer for terminal area surveillance. His seat also moves back to give the captain access to the engineer's console.

The flight instruments and control components are arranged similar to those provided in subsonic jet transports. See Flight Deck Subsystem specification, D6A10109-1, and Systems Report, V2-B2707-11.

3.7 PROPULSION

The B-2707 is powered by either General Electric turbojet or Pratt and Whitney Aircraft turbofan engines. Both engines are in the 60,000 lb thrust class.

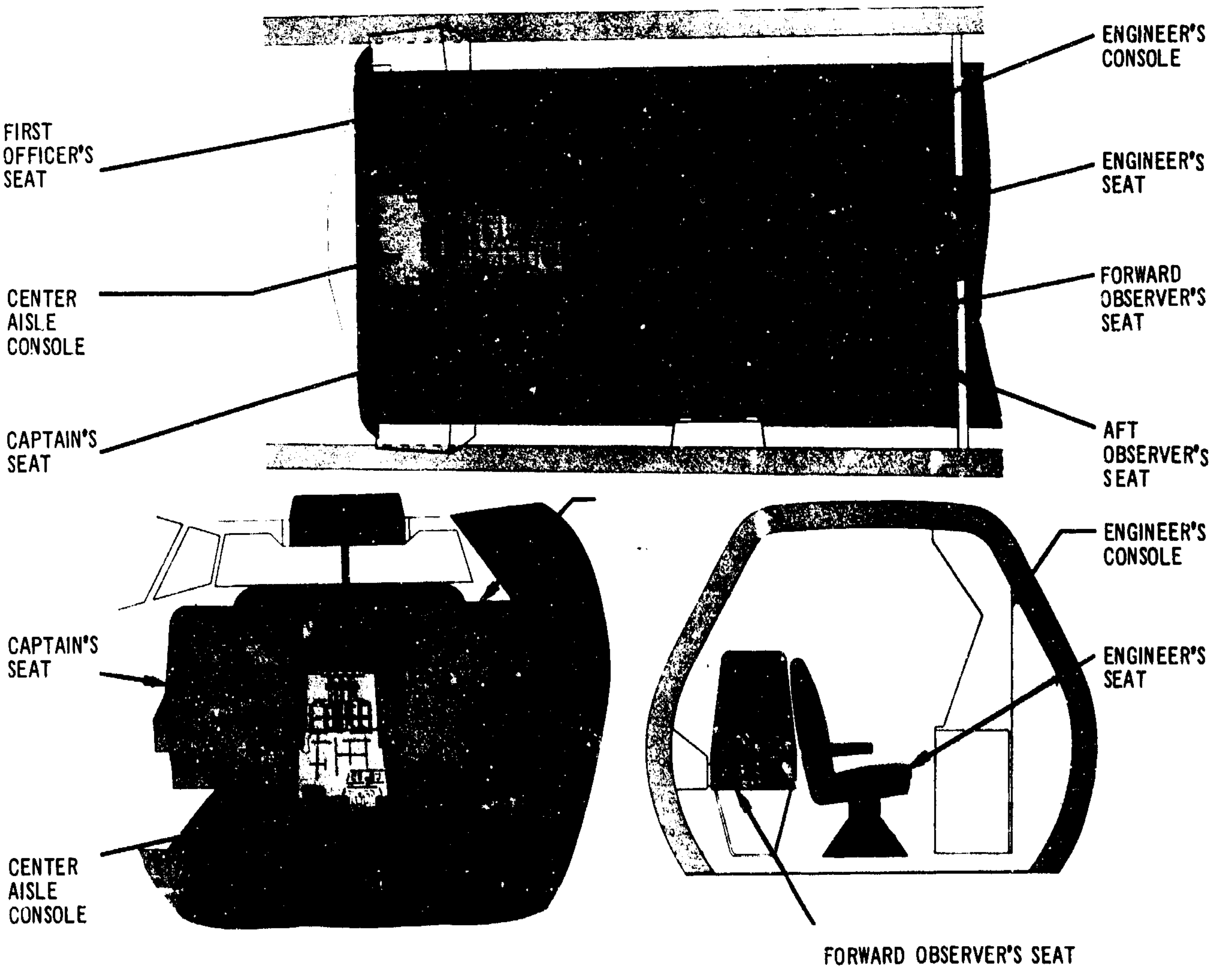


Figure 3-23. General Flight Deck Arrangement

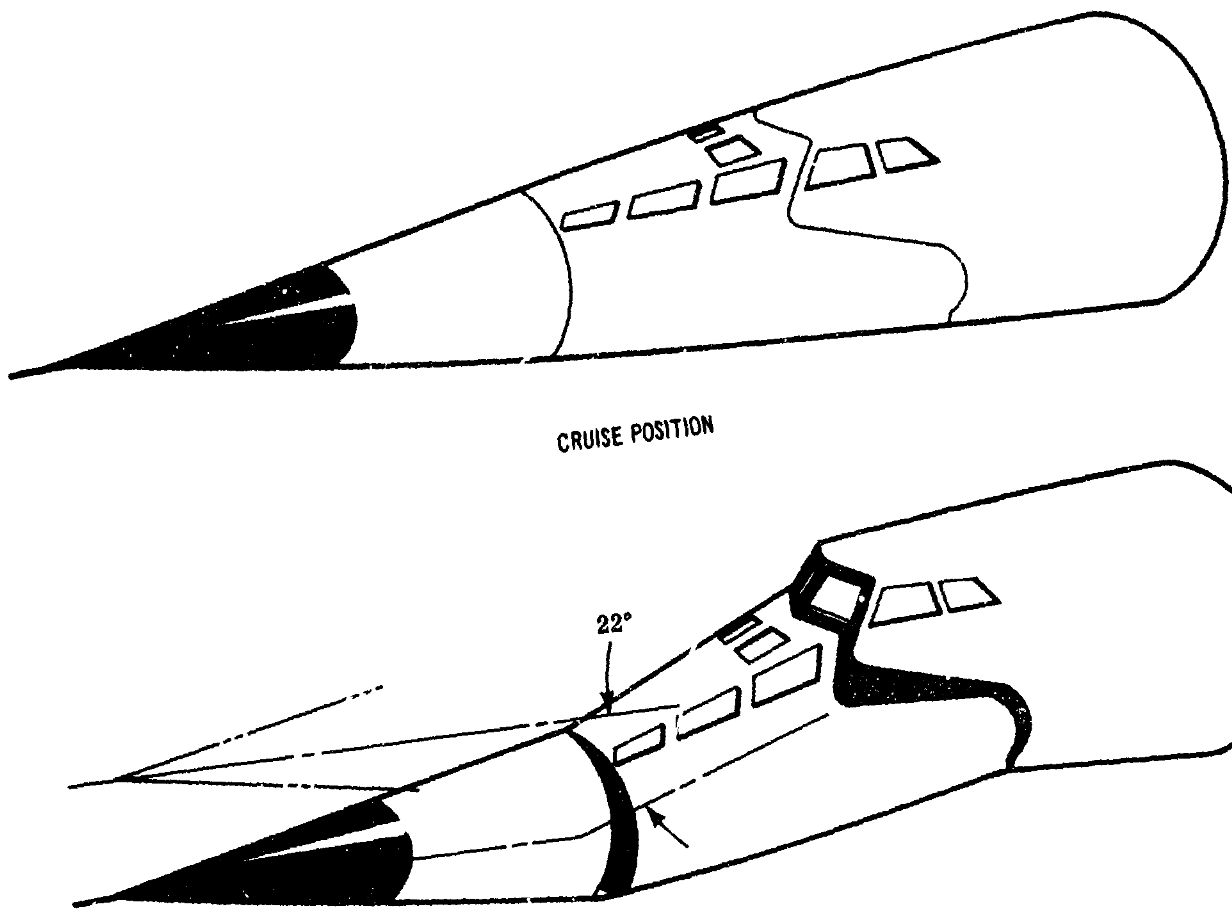


Figure 3-24. B-2707 Forebody

3.7.1 Propulsion Pod
The B-2707 airplane is equipped with four single engine pods located beneath the horizontal stabilizer with exhaust nozzles extending aft of the trailing edge. General Electric or Pratt and Whitney Aircraft engines may be used; pods have been developed for both manufacturers' engines. For a given engine, the same basic engine build-up and pod are used at all four pod locations on the airplane.

The GE pod is shown in Fig. 3-25, and the corresponding pod for the P&WA engine in Fig. 3-26.

The engine pod consists of an axi-symmetric inlet with expanding/contracting centerbody and with cowl bypass doors, the engine, and necessary cowling and accessories. The structural connection between pod and stabilizer is provided by the engine mounts. The inlet is independently mounted to the stabilizer. Air ducts, engine controls, fuel, and instrumentation lines are brought through the upper portion of the pod into the stabilizer. A power takeoff shaft extends into the stabilizer and is connected to a remotely located accessory drive system. The thrust reverser gas flow is directed over and under the stabilizer.

The Boeing inlet variable area centerbody provides airflow match at all flight regimes. In addition, provision has been made to control the centerbody expansion to allow for airflow at Mach 1.0 in the inlet when low noise levels are desired. The Mach 1.0 flow results in a sonic throat; that is, an area where noise propagating forward from the compressor or fan section of the engine is traveling up-stream at the same rate that the airflow is traveling in the opposite direction. Thus, no noise passes beyond this sonic throat, and all discrete frequency noise generated by the compressor is eliminated and noise suppression achieved.

The exhaust nozzles of the GE4/J5P and P&WA JTF17A-21B engines consist of a convergent

nozzle plus a divergent shroud for proper performance at all flight conditions. During takeoff, doors on the shroud are opened and the resulting configuration acts as a nozzle plus ejector. The engine manufacturers have used this ejector to obtain some jet noise suppression. Boeing has increased this "inherent" noise suppression by altering the geometry of the ejector during takeoff. A series of struts (termed chutes by Boeing) have been incorporated into the ejector. This chute-type strut is immersed completely into the supersonic flow allowing the secondary flow to pass beneath it. During flight where noise is not a problem, hydraulic actuators swing the chutes into the ejector wall, thus providing an engine manufacturers nozzle configuration for this part of the flight regime. (See Propulsion Report - Part A, V2-B2707-12.)

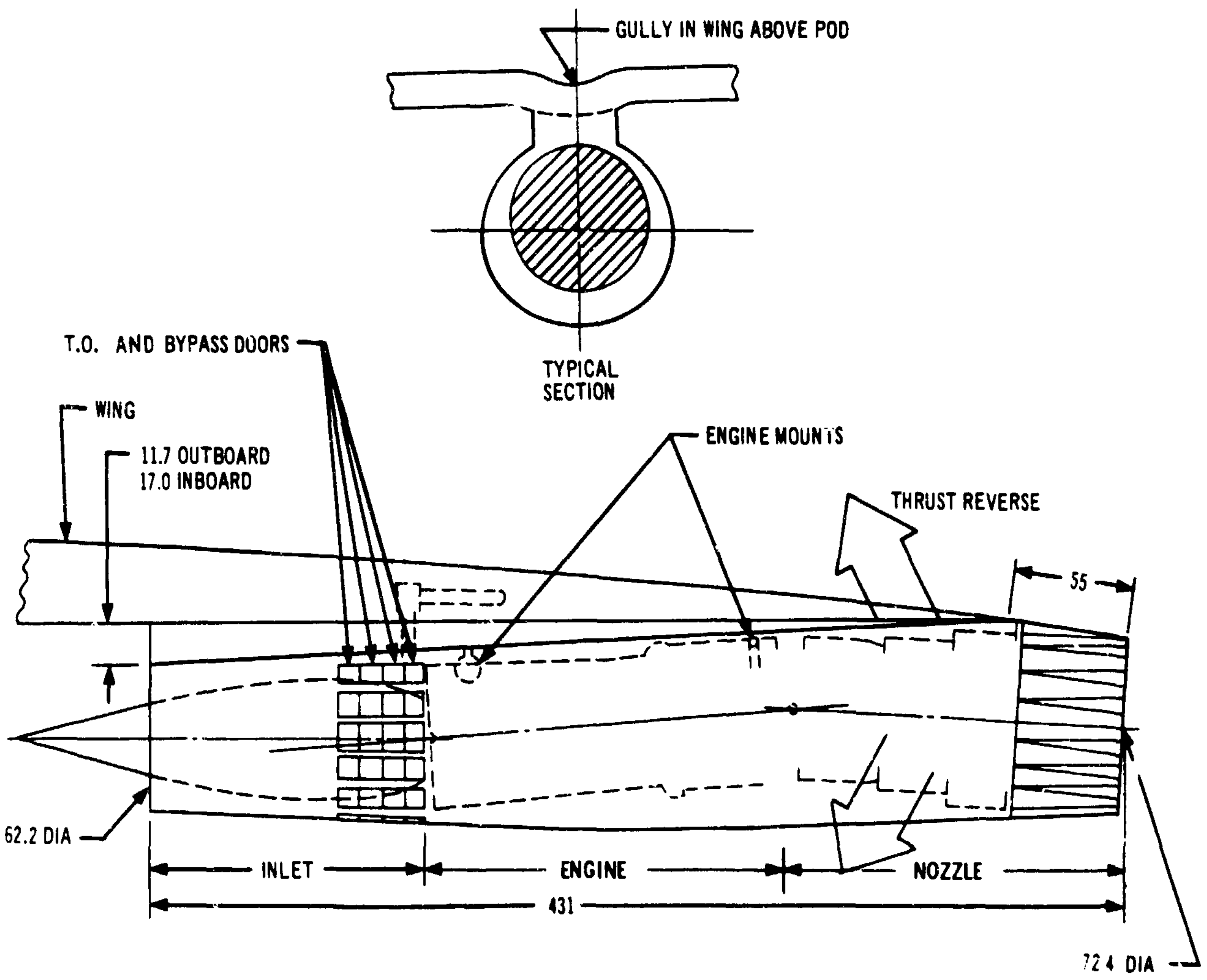


Figure 3-25. GE Pod

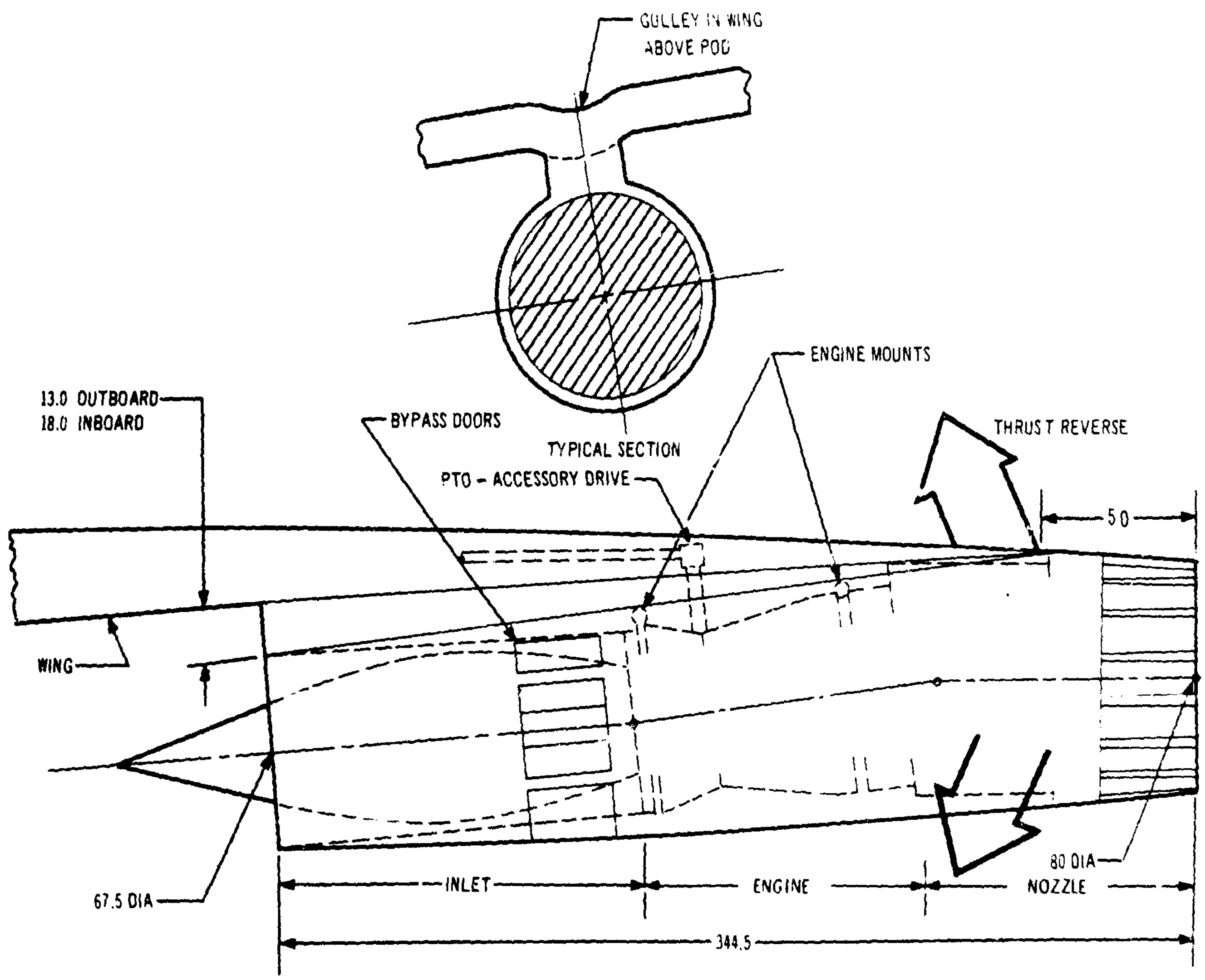


Figure 3-26. P&WA Pod

3.7.2 Fuel System
The fuel system concept provides operational simplicity by allowing the same fuel loading procedure and same fuel use procedure for all flight profiles and passenger loading conditions.

The fuel is supplied directly to specific engines from four main tanks and four auxiliary tanks (Fig. 3-27). The center of gravity control is maintained by a balanced arrangement of the tanks and a simple fuel management procedure. The auxiliary tanks use a high-pressure override pumping system to deliver fuel to their specific engines and are used first. The main tank pumps will then serve as a backup during auxiliary tank usage to provide uninterrupted supply of fuel to the engines when the auxiliary fuel tanks become empty. The system design precludes tank-to-tank transfer because all tanks feed directly to specific engines. A cross-feed manifold, to be used at the pilot's discretion, permits any tank to feed any engine, or combination of engines, in event of abnormal conditions.

Tank inerting and purging are not required and an open vent system is used.

Pressure refueling and defueling is accomplished from left hand and right hand stations located under the fixed wing inboard of the pivots. Two refueling receptacles are provided at each station. Refueling controls are located adjacent to the right hand station.

Inflight fuel jettison provisions are incorporated. A portion of the refueling-defueling system is used for the jettison system. Flow capacity in the fuel pumps will accomplish the jettison through a fixed tail cone discharge.

input at various ADS locations, and to accommodate left and right hand installation on the airplane. The gear-train provides shaft rotation to the driven accessories at the required speed, direction, and torque level. Power input to the gear-train is possible either from the engine through the power shaft, or from the starter in flight. Also, the starter can be used for ground checkout of the various subsystems without running the engines.

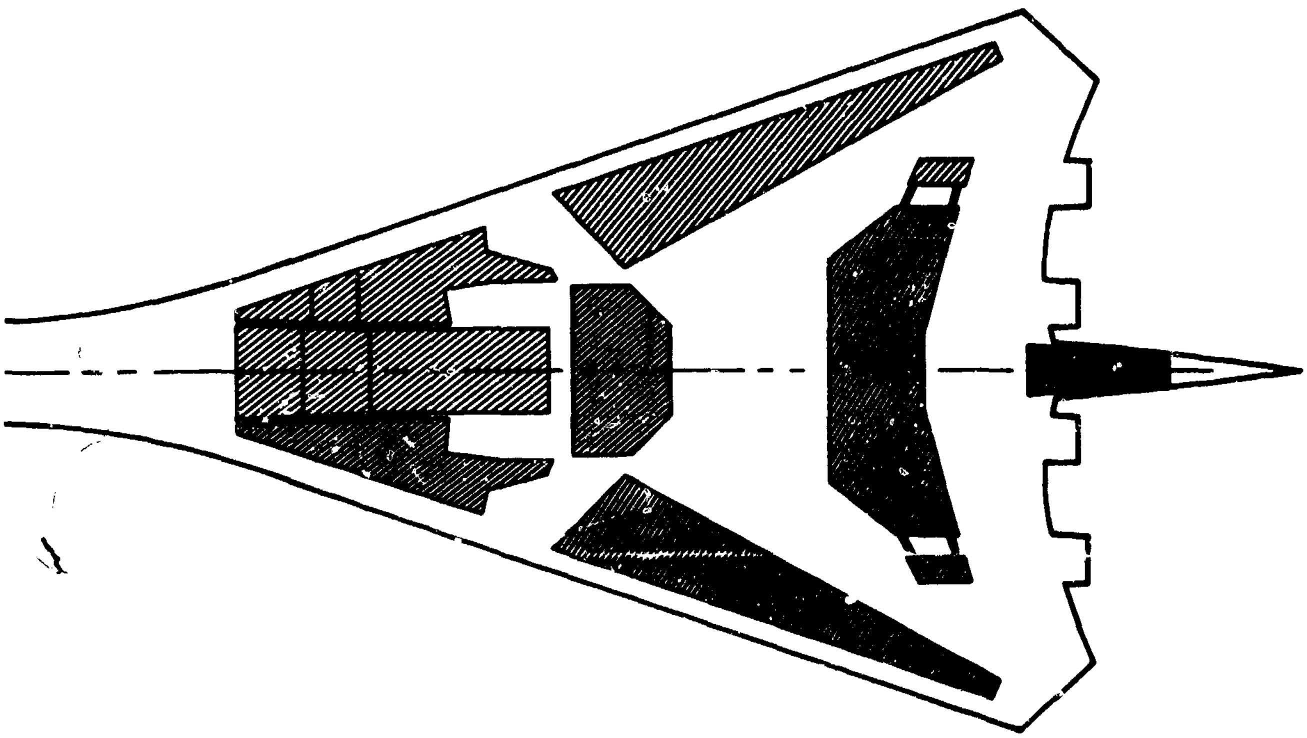


Figure 3-27. B-2707 Fuel Tank Arrangement

3.7.3 Accessory Drive System
The accessory drive system (ADS) provides a mechanical power link between the engine and the accessories. See Fig. 3-28. Four identical ADS modules are employed per airplane, one for each engine.

The general arrangement is shown in Figs. 3-29 and 3-30.

An angle drive designed as part of the gearbox enables the gearbox to accept engine shaft power

The configuration allows engine replacement without the need for breaking into the electric, hydraulic, or environmental control subsystems.

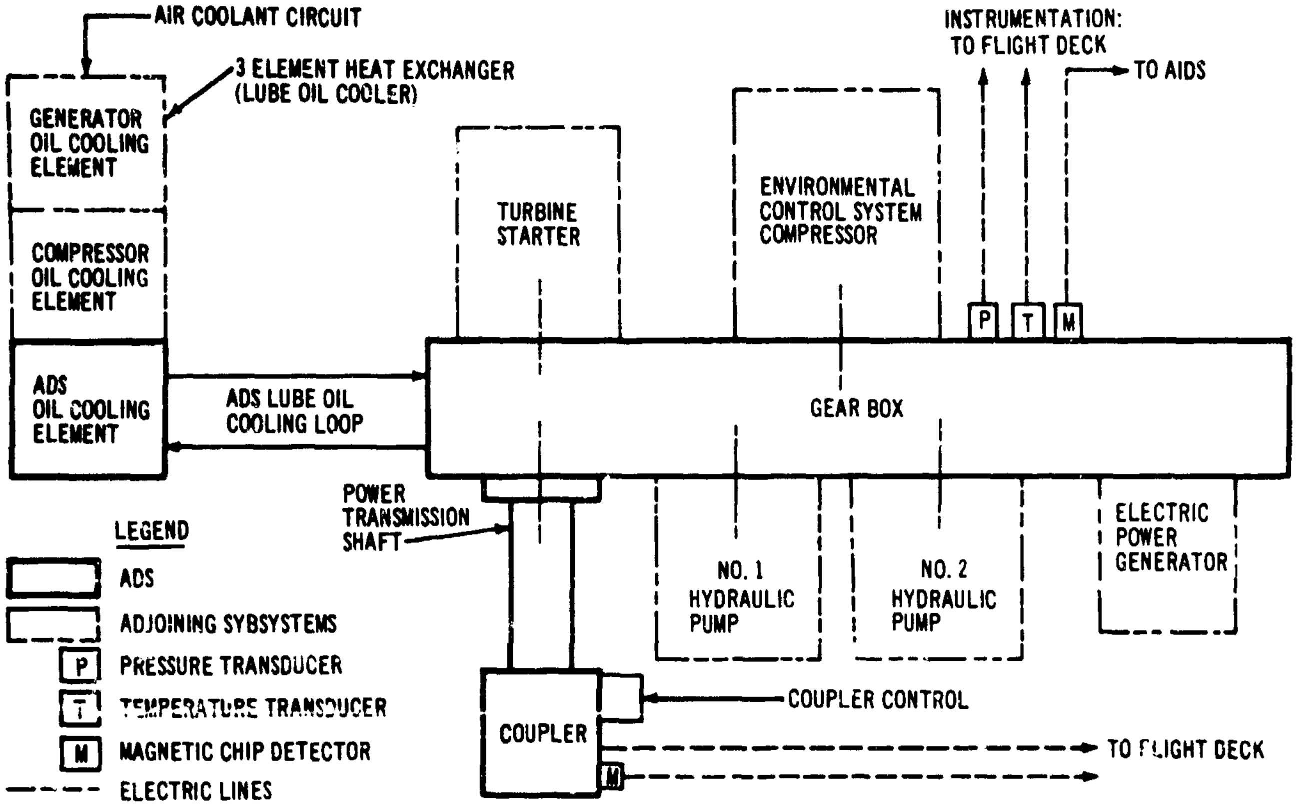


Figure 3–28. Accessory Drive System

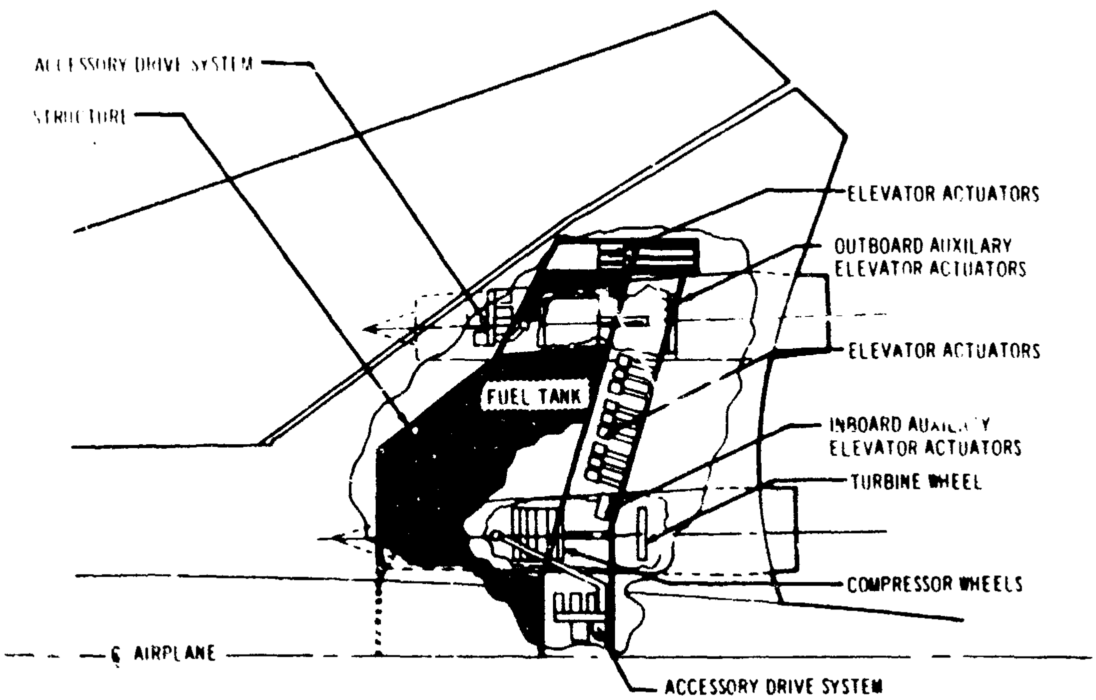


Figure 3–29. Accessory Drive System B–2707 (GE)

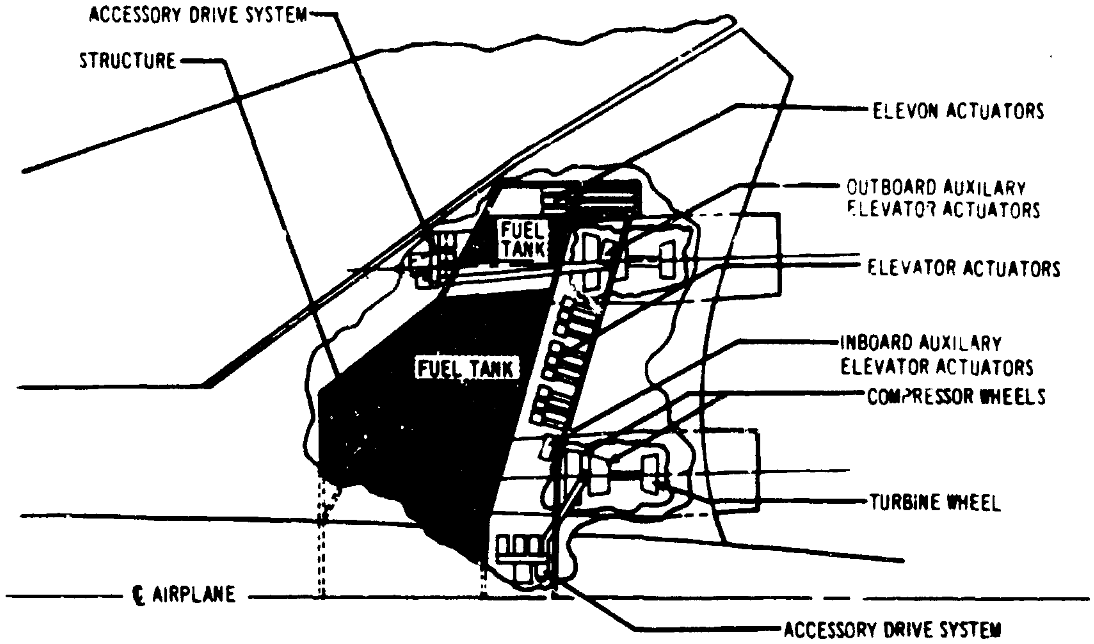


Figure 3-30. Accessory Drive System B-2707 (P&WA)

3.8 ELECTRIC SYSTEM

Electric power is derived from four variable frequency, oil-cooled, brushless, 10,000- to 20,000-rpm generators each driven by an accessory drive gearbox (Fig. 3-31). The 1,200- to 2,400-cps power is converted to 400 cps constant frequency in four frequency converters. Each generator-converter channel delivers 60KVA, 400 cps power to its main bus.

The four generating channels are connected together through a tie bus arranged so that the individual generator channels may be operated isolated, split-parallel or parallel in any combination desired. The paralleling and isolating functions are accomplished with bus tie breakers and synchronizing tie bus isolation breakers.

The ac power is distributed from the frequency converters in the rear of the airplane. Direct current 28V power for control of the airplane electric systems is derived from six transformer-rectifier units which are rated at 75 amperes each. The T-R units are installed and connected in pairs for 100-percent redundancy.

The standby power system consists of two batteries, a normal battery for ground use and standby battery for flight use, and an inverter with associated chargers and controls. External power may be connected to the airplane to supply all electric loads.

Controls for the system are provided at the engineer's control stand and the external power receptacle.

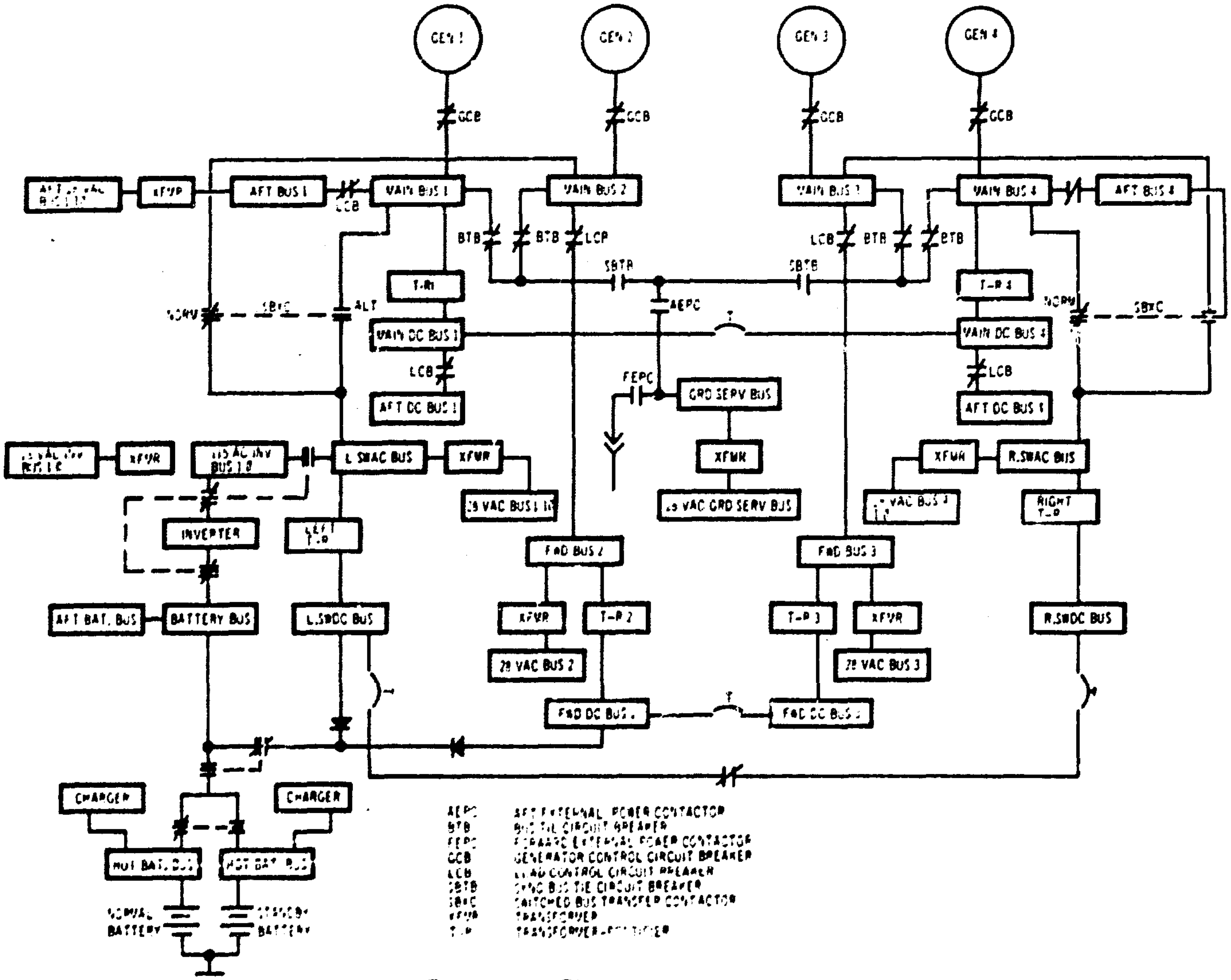


Figure 3-31. Electrical Power Generation

3.9 FLIGHT CONTROLS AND HYDRAULICS

3.9.1 Flight Controls

Fig. 3-32 illustrates the control surfaces of the B-2707. The primary flight controls consist of elevons, elevators and auxiliary elevators for pitch control; ailerons and spoilers for low-speed roll control; elevons and spoilers for high speed roll control; a rudder for yaw control and variable sweep wings for optimum lift/drag characteristics. The normal mode of operation of the pitch and roll systems employs an electric command subsystem, whereby pilot control forces are transmitted electrically to a pitch master servo and a roll master servo which in turn transmit mechanical control inputs to pitch and roll surface actuators. Dual mechanical cables from each control wheel and column provide the alternate mode by which the pilots may control the master servo. Rudder pedal movement is transmitted to the rudder surface actuator by mechanical cables. All primary flight control surfaces are positioned by irreversible hydraulic actuators. Mechanical linkages which transmit primary flight control signals incorporate a dual load path design.

The secondary flight controls consist of wing trailing edge flaps, leading edge slats, trim provisions, and speed brakes. Dual mechanical

cables from each control wheel and column provide the alternate mode by which the pilots may control the master servo.

The elevons, primary elevators, inboard auxiliary elevators, ailerons, spoilers, rudder, wing sweep actuator and outboard wing trailing edge flaps are powered by three separate hydraulic systems, designated A, B, and C. The outboard auxiliary elevators, inboard wing flaps and inboard and outboard wing leading edge slats are powered by two separate hydraulic systems (A and B). The hydraulic systems are not interconnected.

The relationship of control surface operation to flight mode and wing sweep position is shown in Table 3-B.

The primary elevators are used for pitch control in all flight conditions while the elevons are operated differentially for both pitch and roll control in supersonic flight. With the wings forward the elevons are operated in unison with the elevators for pitch control only. Additional pitch control is obtained with the auxiliary elevators when the flaps are down.

Roll control is through the ailerons and spoilers with wings forward and flaps in the take off or landing position. As the flaps are retracted and wings moved aft, roll control is transferred to the elevons and augmented by the spoilers. A small amount of the roll control commands are also fed into the rudder to provide automatic turn coordination.

A rudder is used for yaw control.

All trim systems are of the parallel type; i.e., adjustment of the trim control moves the pilots' controls to indicate the trimmed position. All three systems are trimmed by electric control and an additional manual mechanical control is provided on the pitch system.

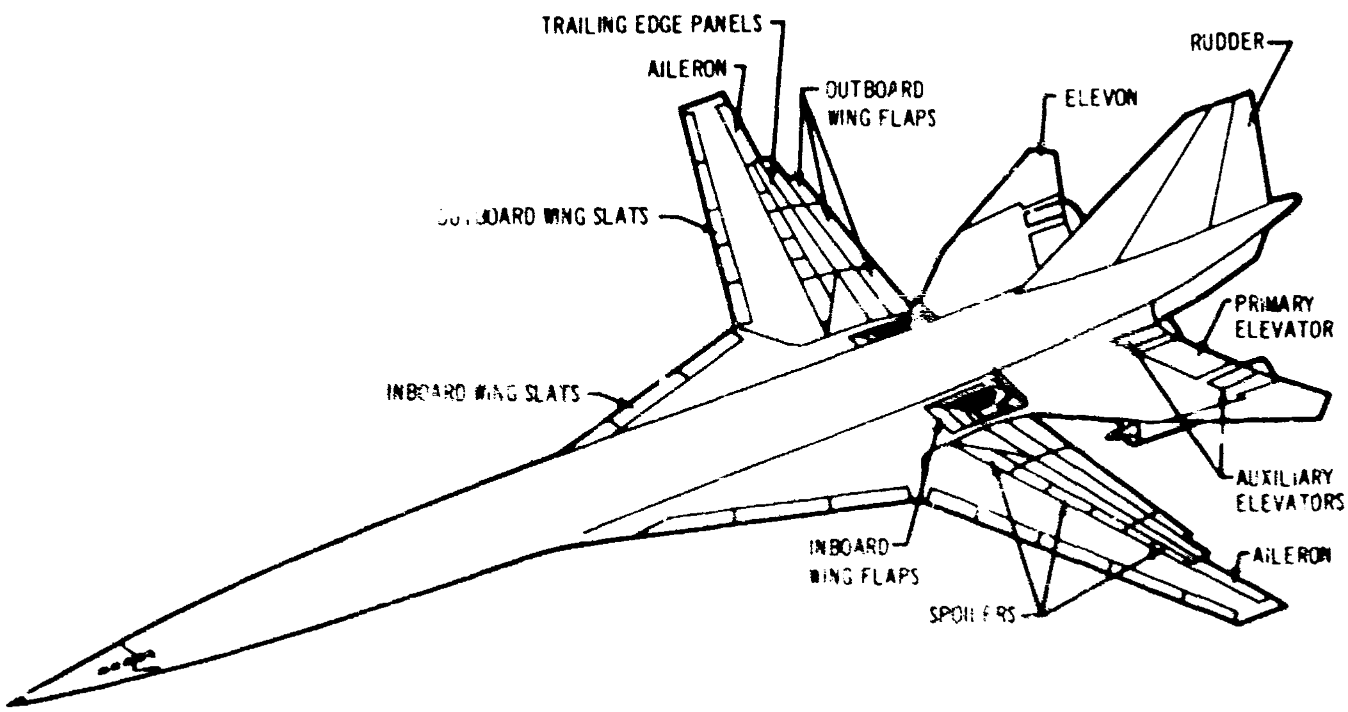


Figure 3-32. B-2707 Flight Control Surfaces

Table 3-8. Control Surface Operation Versus Flight Mode

FLIGHT MODE	WING SWEEP	ELEVONS	PRIMARY ELEVATORS	AUXILIARY ELEVATOR	AILERONS	SPOILERS INBOARD	SPOILERS OUTBOARD	RUDDER	FLAPS IN	FLAPS OUT	SLATS IN	SLATS OUT
T O V_e 225 KNOTS	30°	P(±30°)	P(±30°)	P(0 - 30°)	R(±25°)	R(0 - 45°) B(0 - 45°)	R(0 - 45°) B(0 - 45°)	Y(±25°)	40°	20°/40°	35°	20° 37.5°
SUBSONIC M_{M_O} .5	30°	P(±30°) R(±10°)	P(±30°)	0	0	R(0 - 45°) B(0 - 45°)	R(0 - 45°) B(0 - 45°)	Y(±12°)	0	FAIRED (EXTENDED)	25°	6°
SUBSONIC M_{M_O} .9	42°	P(±30°) R(±14°)	P(±30°)	0	0	R(0 - 45°) B(0 - 45°)	R(0 - 45°) B(0 - 45°)	Y(±12°)	0	FAIRED (EXTENDED)	0° 25° ▷1	0° 6° ▷1
SUBSONIC M 0.5	72°	P(±25°) R(±20°)	P(±30°)	0	0	R(0 - 45°) B(0 - 45°)	0	Y(±12°)	0	0	25°	0
SUPERSONIC M_{M_O} 2.7	72°	P(±25°) R(±20°)	P(±10°)	0	0	R(0 - 45°) B(0 - 45°)	0	Y(±8°)	0	0	0	0
LANDING V_e 195 KNOTS	30°	P(±30°)	P(±30°)	P(0 - 30°)	R(±25°)	R(0 - 45°) B(0 - 45°)	R(0 - 45°) B(0 - 45°)	Y(±25°)	40°	30° 50°	35°	30° 35°

P - PITCH CONTROL   R - ROLL CONTROL   Y - YAW CONTROL   B - SPEED BRAKES   ▷1 Req'd to M.05

3.9.2 Wing Sweep and High Lift
Position of the wings is controlled by ball screws, one at each pivot, actuated by a dual load path mechanical drive system from a central gear box in the body. Power is supplied by three hydraulic systems (A, B and C), any one of which can develop the full torque to drive the ball screws at a reduced rate. See Fig. 3-33. Each drive screw is of dual load path construction and equipped with no-back brakes to make it irreversible. An asymmetry shut-off system limits the out of symmetry position of the wings to a safe value, should there be a double failure in the drive system.

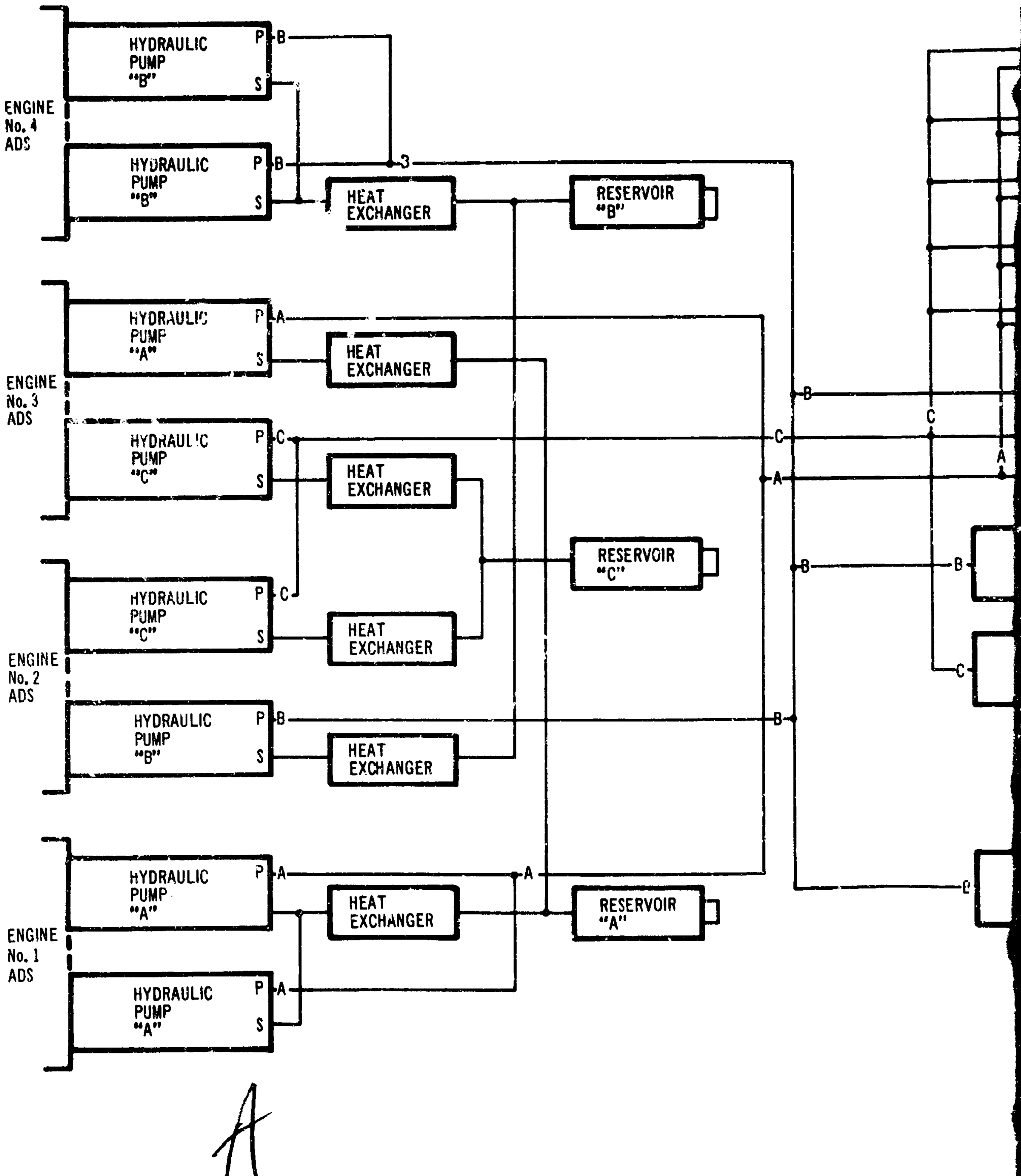
The high lift surfaces used to improve low speed performance are the inboard wing trailing edge flaps, outboard wing trailing edge flaps, inboard wing leading edge slats and outboard wing leading edge slats. Five separate drive systems are utilized as shown in Fig. 3-34. The high lift surface operation is sequenced with wing sweep operation by a flap/wing sweep mechanical programmer to prevent incompatible positions. The interrelationship of the flaps and slats with wing sweep is shown in Fig. 3-13. Each drive system is provided with power from either two or three hydraulic power systems.

3.9.3 Hydraulic Power
The hydraulic power subsystem consists of three independent basic systems, designated A, B and C, and one standby system as shown in Fig. 3-33. There is no fluid inter-connection between systems. All three systems are used to power the flight controls.

Eight 125 gpm positive displacement, variable volume pumps supply hydraulic power at 3,000 psi. The arrangement of the pumps is such that the loss of any one engine, or two engines on one side, will not cause the loss of any hydraulic system. The loss of any two engines will not cause the loss of more than one hydraulic system.

The standby hydraulic system provides the following functions:

- Furnishes independent hydraulic power to the standby brake system.



ENGINE No. 4 ADS
HYDRAULIC PUMP "B"
HYDRAULIC PUMP "B"
HEAT EXCHANGER
RESERVOIR "B"
ENGINE No. 3 ADS
HYDRAULIC PUMP "A"
HEAT EXCHANGER
HYDRAULIC PUMP "C"
HEAT EXCHANGER
RESERVOIR "C"
ENGINE No. 2 ADS
HYDRAULIC PUMP "C"
HEAT EXCHANGER
HYDRAULIC PUMP "B"
HEAT EXCHANGER
ENGINE No. 1 ADS
HYDRAULIC PUMP "A"
HEAT EXCHANGER
RESERVOIR "A"
HYDRAULIC PUMP "A"
A

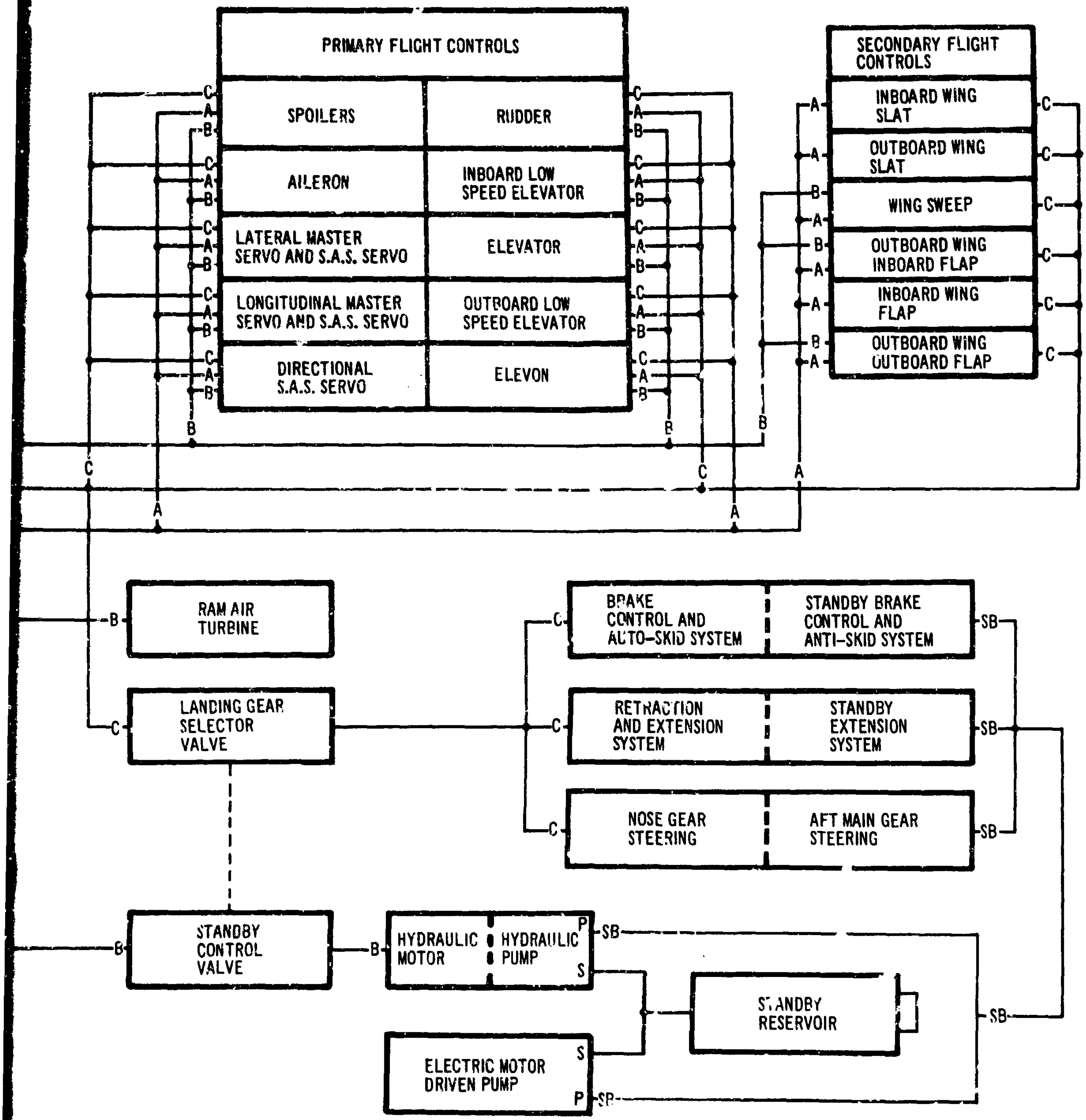


Figure 3-33. Hydraulic System

3

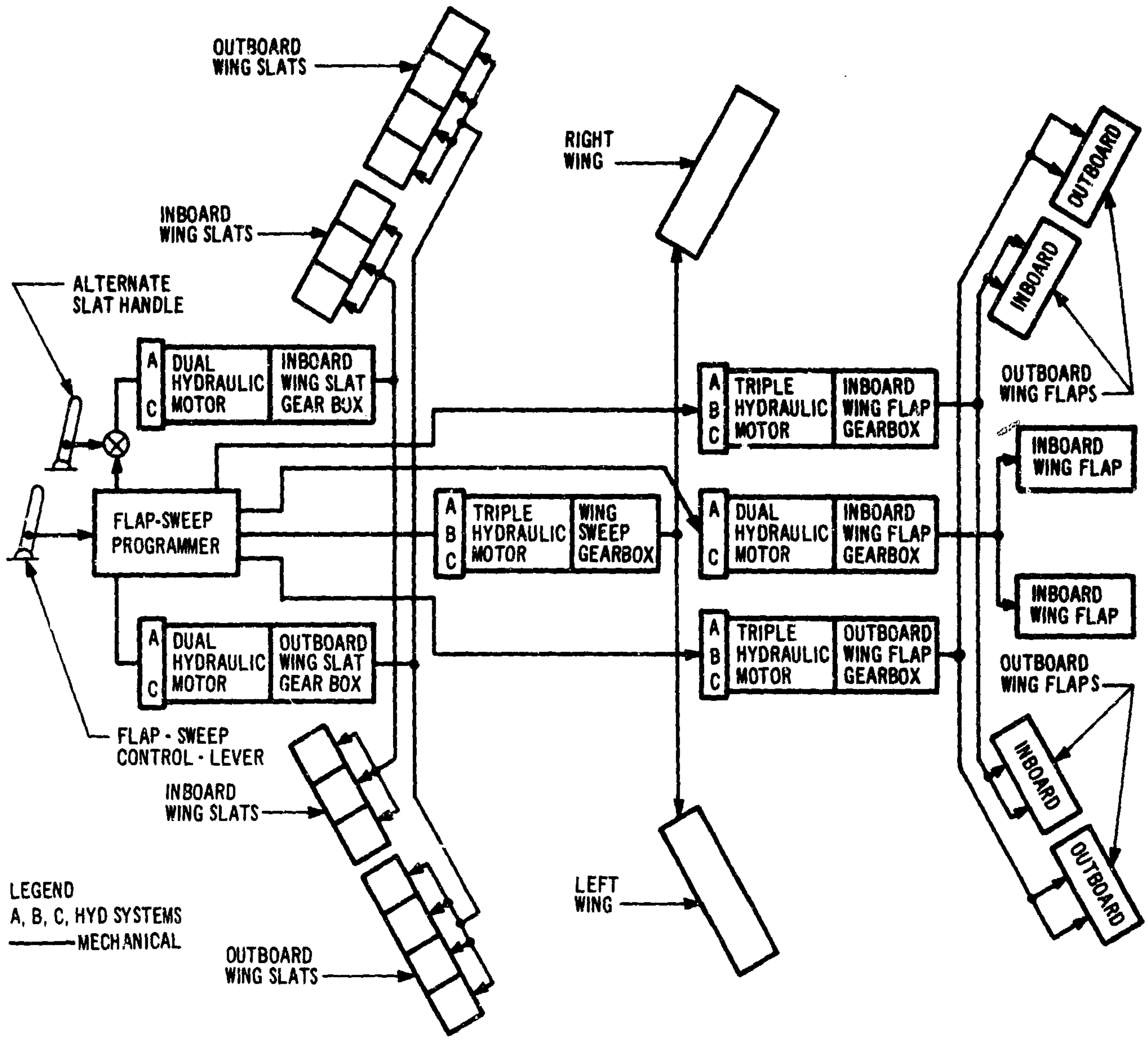


Figure 3-34. Wing Sweep and Flap System Block Diagram

- Supplies power to the standby gear extension system.
- Supplies power for steering and braking during towing.

The standby system obtains its power from a positive displacement fixed volume pump driven by a hydraulic motor in the "B" system, operated only when the landing gear handle is "down." A second standby power source, an ac electric motor-driven pump, is available for ground operation power and as a third means of extending the gear should both "B" and "C" systems fail.

A ram air turbine driven pump unit is installed in the "B" system. This unit is used to augment windmilling engine power for flight control if all engines should fail.

The hydraulic fluid to be used is WSX-6885, manufactured by Humble Oil and Refining Company.

Except for an improved oxidation additive, WSX-6885 is chemically identical to Humble ETO-5251, the engine oil currently in use on subsonic jets.

Hydraulic fluid is cooled by individual fluid-to-fuel heat exchangers, to a maximum of 250°F on the pump inlet lines to insure adequate pump life. During descent, when fuel flow is reduced, cooling of the hydraulic fluid is through ram air-to-fluid heat exchangers.

Two engine-driven pumps are mounted on each accessory drive gearbox. Reservoirs, filters and other system accessories are located in the hydraulic equipment bay. Hydraulic lines are of 6AL-4V titanium with permanently welded fittings in 75 percent of the system. Where reconnectable fittings are required, Resistoflex Dynatube fittings are used. Hydraulic swivels are employed for the lines passing through the wing pivots.

3.9.4 Automatic Flight Control System (AFCS)
The AFCS provides:

- Improvement of the airplane's handling characteristics, response and stability under all flight conditions.
- Automatic control of flight direction, speed, altitude, and attitude for pilot relief.
- Automatic control of approach and landing during adverse weather conditions.

Components of the system include the electric command, the autopilot, including the autothrottle, and the stability augmentation system (SAS). Fig. 3-35 shows the relationship of these components within the navigation and control systems.

(a) Pitch Modes
Calibrated airspeed hold
Rate-of-climb select
Mach-altitude schedule control
Altitude hold control
Altitude capture control
Glide slope control (automatic capture)
Auto land
Go-around/takeoff control

(b) Roll Modes
Roll attitude/heading hold control
Heading select control
Localizer control
VOR control
Inertial navigation control
Wings level control
Rough air

The stability augmentation system of the pitch, roll and yaw axes operating through series servos, provides the following functions:

- Handling qualities improvement, including Dutch roll damping and turn coordination.
- Autopilot inter-loop damping.
- Alleviation of structural loads.

Multiple redundancy is employed in the AFCS and SAS to assure high reliability.

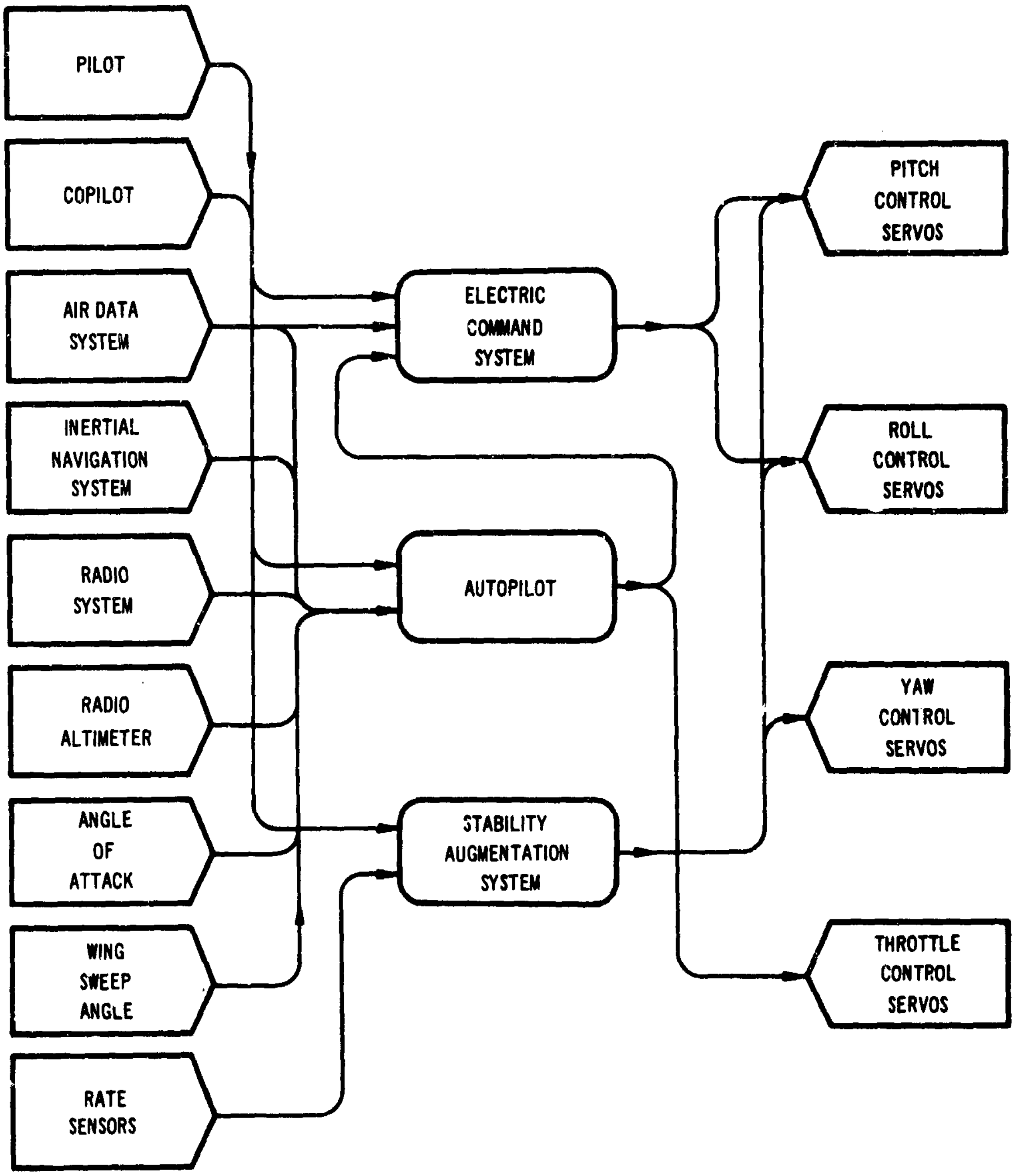


Figure 3-35. Control and Navigation Systems Relationship

3.10 COMMUNICATION/NAVIGATION

Communication and navigation systems in the B-2707 provide the same capabilities as currently in use in subsonic jets. Provisions for inertial navigation and clear air turbulence detection, collision avoidance are also included. These systems are outlined in Navigation/Communication Subsystem Specifications, D6A10122-1. The following briefly describes the additional systems noted above:

a. Inertial Navigation System

The system consists of three Aeronautical Radio, Inc., Characteristic No. 561, Air Transport Inertial Navigation Systems; three standby battery units for system operation during aircraft power interruptions; dual converter units for derivation of stabilized magnetic azimuth detectors to sense the earth's horizontal magnetic field vector; a switching unit to allow the third or standby INS navigation and guidance data to be switched to either the captain's or first officer's instruments; and an interface unit for integration of the system and components and proper signal routing.

Each inertial navigation system includes: (1) a self-contained navigation unit consisting of a stable platform that senses aircraft accelerations and attitudes and a digital computer that performs the data processing function, derives attitude, navigation, and guidance information, and performs system performance monitoring functions; (2) a display unit to provide readout of navigation and guidance data on a selectable basis, capable of data entry and system health monitoring; and (3) a control unit for system mode control.

Parameters displayed are: present and waypoint latitude and longitude, true heading, ground speed, drift angle, cross track deviation, present track angle, time to next waypoint, distance to waypoints, wind speed and direction, course change warning, waypoint code select, and six system status annunciators.

b. Clear Air Turbulence

Research being conducted for a means of detecting clear air turbulence has indicated that by the operational period of the B-2707, a practical solution will exist. Therefore, space has been provided for anticipated electronic equipment.

c. Collision Avoidance

Collision avoidance systems are also receiving considerable research effort. It is expected that a cooperative system and suitable computing functions will enable the determination of speed, direction and altitude of other aircraft within a reasonable avoidance area. Rack provisions for anticipated requirements are reserved.

The antenna systems have been located on the aircraft in a manner consistent with maximum system efficiency and minimum interference with other airplane elements. Antenna size, weight, and efficiency has been stressed throughout the electronics design and research program. Fig. 3-36 illustrates the location of the antennas on the airplane.

The principal location - sensitive antennas are those serving the automatic direction finder, the glide slope and localizer receivers, the weather radar, and the radio altimeters.

The location of the ADF sense antenna received particularly close attention because of its operational importance. The antenna is installed forward of the main gear beneath the body fuel tank. Cavity depth is sufficiently small such that the lower surface of the fuel tank is virtually uninterrupted.

The glide slope and localizer antenna locations are critical in that they determine the relative location of the airplane landing gear to the glide path and runway centerline during the approach and landing mode. The glide slope antenna is located near the airplane center of gravity and as near to the landing gear as possible. This minimizes the vertical displacement from the bottom of the landing gear to the glide slope antenna and, thereby, provides a configuration meeting the runway threshold requirement.

The localizer antenna is installed near the airplane center of gravity to ensure that the landing gear will be centered on the runway during a crosswind landing. The glide slope and localizer antennas are installed on both sides of the airplane within the wing leading edge adjacent to the fuselage. Both systems provide adequate coverage for the localizer and glide slope beams.

The weather radar antenna is located on the nose of the aircraft in order to detect and, subsequently, avoid severe weather disturbances which

From III A 3 (Safety)

Oxygen System

The B-2707 does not contain a passenger oxygen system. Boeing indicates none is required due to the integrity of their pressurization system and fuselage structure, which they state precludes cabin altitude exceeding 15,000 feet following any double failure in the pressurization system, or a pressure vessel leakage combined with a single failure in the pressurization system.

From-~~Safety~~ ~~Tannenbaum~~

10 ~~min~~ 10%

• The B-2707 does provide for a ~~passenger~~ oxygen system in the case of emergency. This system which provides protection to the crew ~~and 300 passengers including flight students, is presented in~~ V2-B2707-10 pp. 1/30-31.

S.J. Gustketch[illegible]

may lie in the airplane's flight path. The moveable forebody allows the antenna to move with respect to a vertical axis when the nose is in the "down" position.

The radio altimeter provides critical altitude information to the autopilot during the final stages of an automatic landing. The antennas are installed on the bottom centerline of the body aft of the main gear where they conveniently fit within the depth of the body frames and do not intercept usable internal space. The antennas must be located so that their downward field of view will not be obstructed by objects such as an engine nacelle or landing gear or else the system could "lock on" to one of these objects.

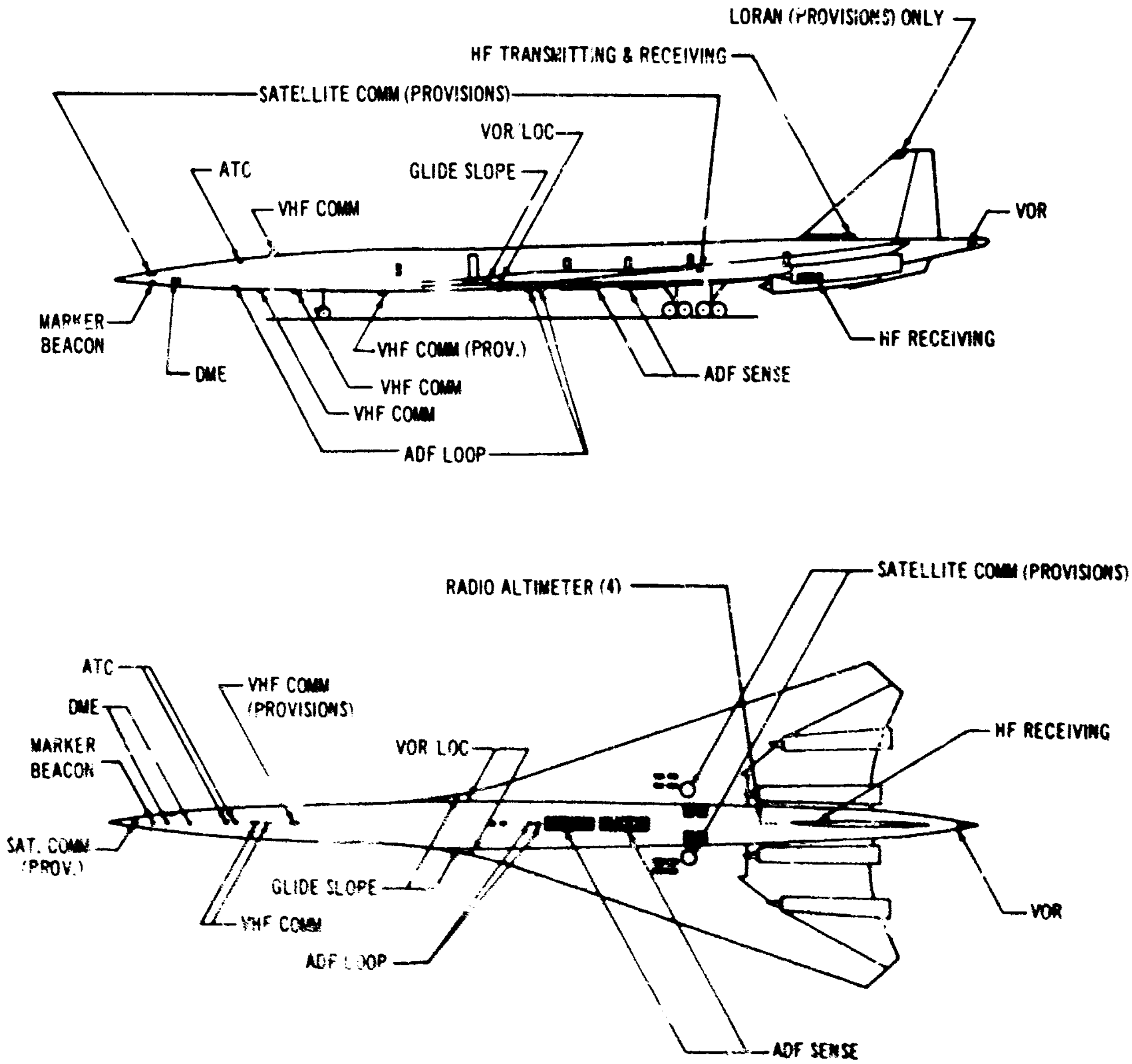


Figure 3-36. Antenna Locations

3.11 ENVIRONMENTAL CONTROL SYSTEM

The environmental control system includes an air conditioning system, an adverse weather system, and an oxygen system.

The air conditioning system is comprised of four separate air sources and conditioning and controlling units serving separately the flight deck and the three main sections of the passenger cabin. It also supplies cooling air to cargo compartments, equipment bays, wheel wells, and the weather radar. See Fig. 3-37.

The normal air source for each air conditioning channel is ram air from an engine inlet feeding a boost compressor on the accessory drive system associated with that engine. See Fig. 3-38. The compressor delivers air to a bootstrap air cycle cooler using air-to-air and air-to-fuel heat exchangers as required by the current phase of flight. The air then flows into the distribution and control system serving the assigned portion of the cabin. Instrumentation and controls are provided for management of the ECS and includes ozone and radiation monitors.

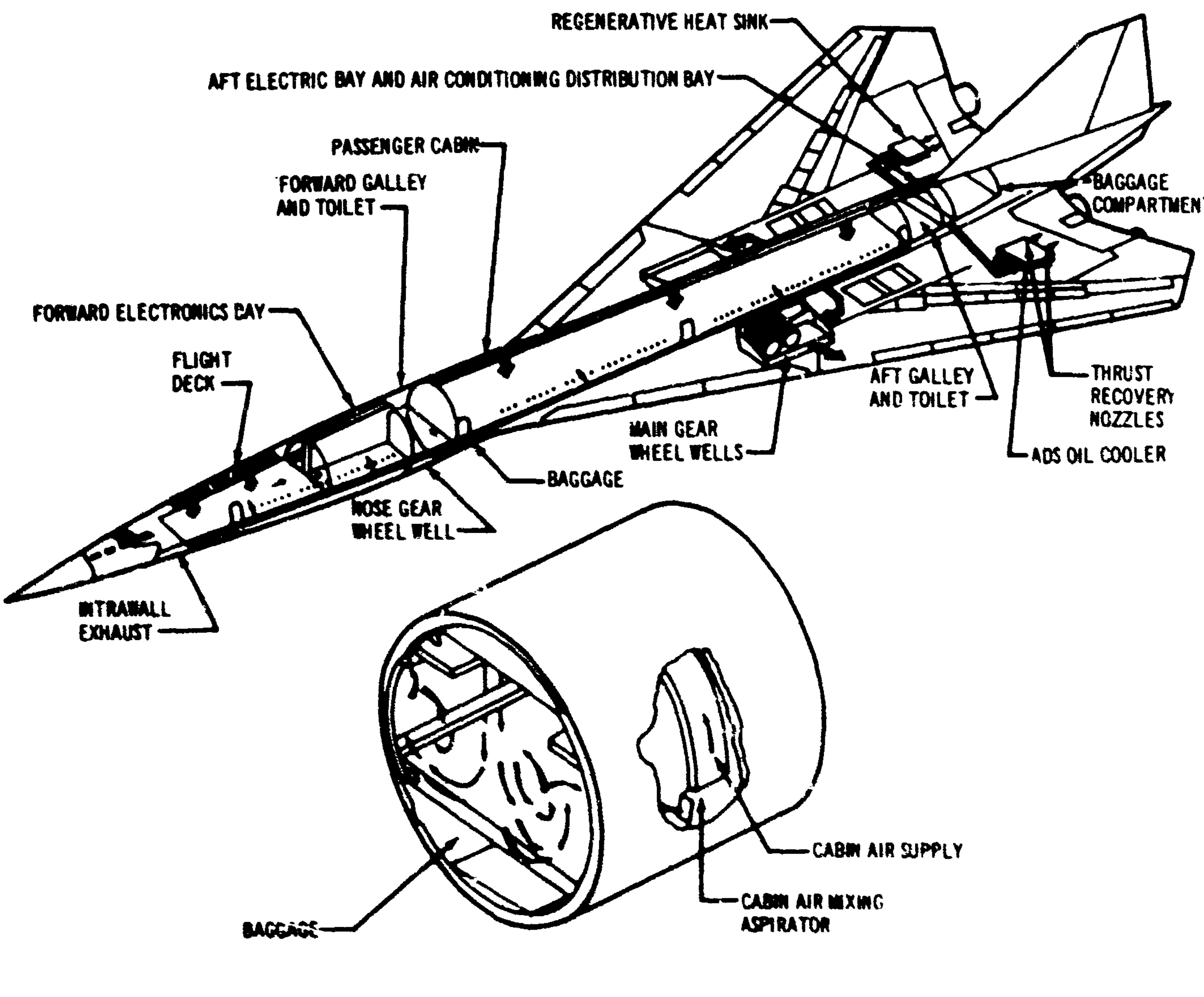


Figure 3-37. Conditioned Air Utilization

V2-B2707-1

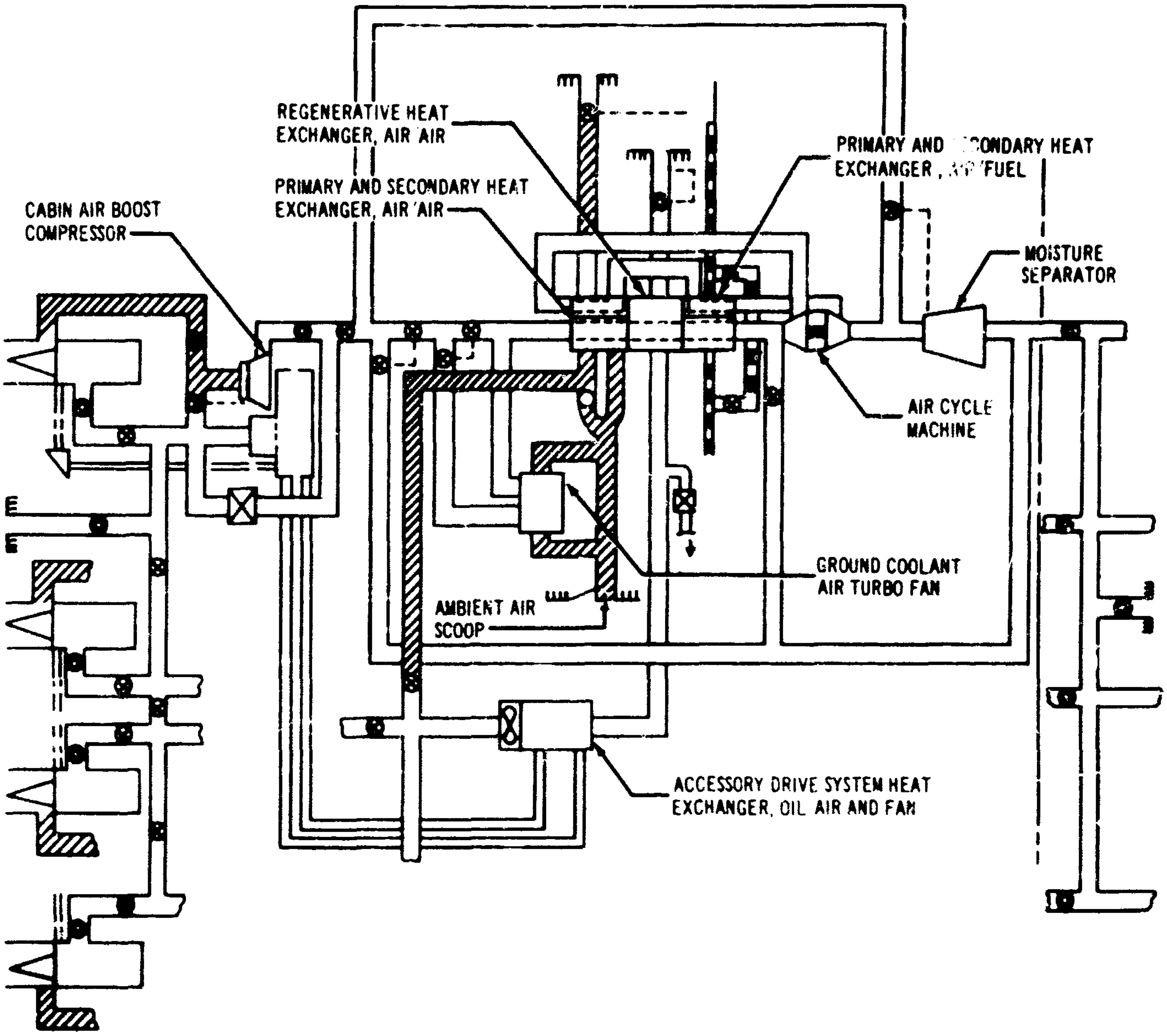


Figure 3-38. Air Condition Supply System

Cabin exhaust air is led into the equipment bays, cargo compartments, and the wheel wells, as well as to the pressurized portion of the weather radar to maintain required environment in those zones.

The four-channel system allows dispatch of the airplane with one channel inoperative, the other three maintaining environmental control requirements with reduced circulation rate. In the event of failure of any inlet-boost compressor air source, the system allows immediate substitution of engine bleed air with no loss of volumetric capacity.

The adverse weather system includes ice and fog protection and rain removal for the flight deck windshields. Fog protection is provided for the moveable nose side windows. Ice protection is provided for the engine inlets and air data sensors.

The oxygen system includes a liquid oxygen system for the flight crew members and portable

first aid oxygen units for the passenger cabin occupants and flight crew members.

The cabin altitude will not exceed 14,000 ft in the event of a skin failure between adjacent frames and stringers of 42 sq in., or a passenger window blowout. In the event of a rapid decompression, a signal from the cabin altitude rate-of-change sensor causes the cabin air compressor to provide increased flow. Cabin altitude transients following a passenger window blowout or a 42-sq. in. panel blowout with three and four air sources are shown on Fig. 3-39 and 3-40, respectively. The predicted cabin temperature is shown on Fig. 3-41.

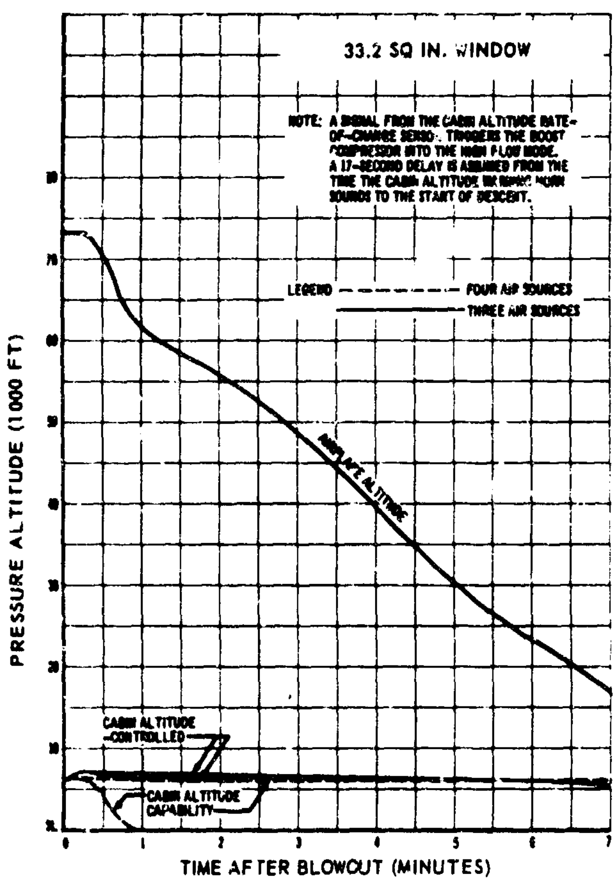


Figure 3-39. Cabin Altitude-Window Blowout

The cabin altitude transient during the emergency descent following the failure of all engines is limited to 14,000 ft with airflow provided from one cabin compressor driven by a windmilling engine. The cabin altitude transient is shown on Fig. 3-42.

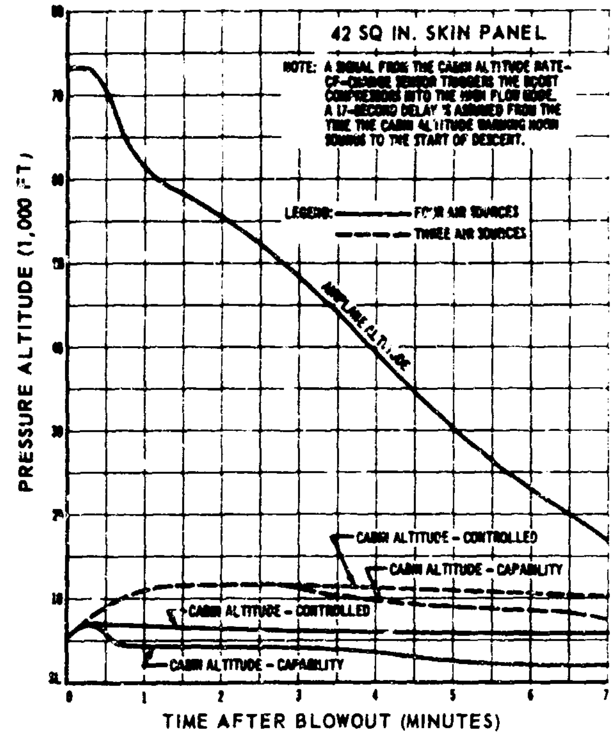


Figure 3-40. Cabin Altitude-Skin Panel Blowout

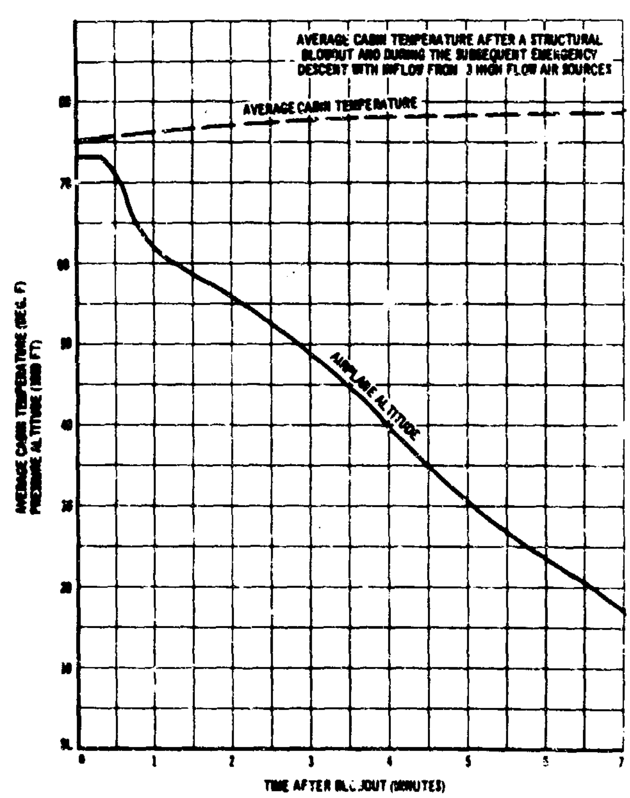


Figure 3-41. Cabin Temperature After Blowout

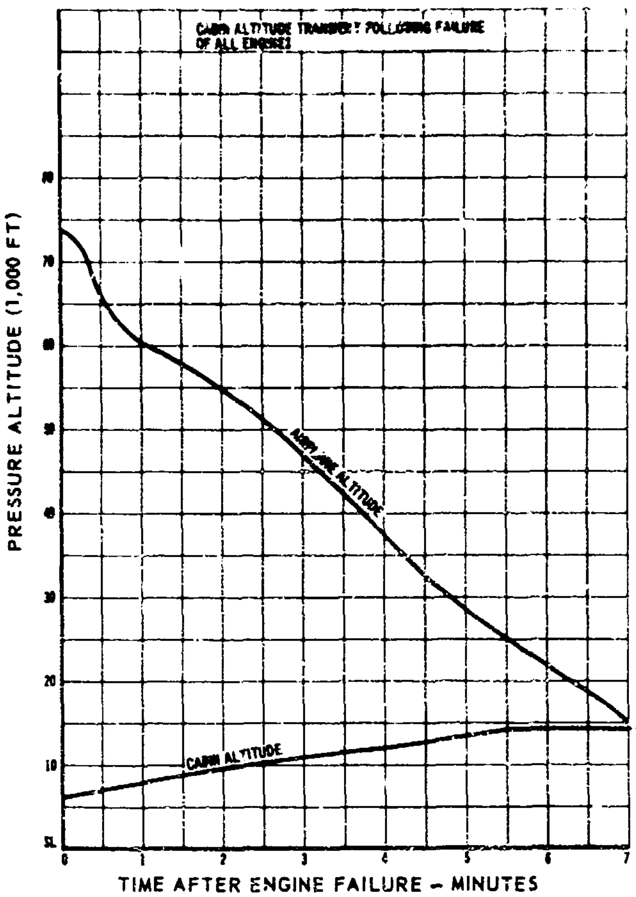


Figure 3-42. Cabin Altitude—Engine Failed

3.12 EQUIPMENT ACCESS AND ENVIRONMENT PROTECTION

The overall design of the B-2707 gives maximum consideration to accessibility provisions for performing maintenance, servicing, and inspection. Fig. 3-43 illustrates access provisions. B-2707 design provides the following:

a. Plug type doors are provided for access to pressurized equipment bays. The doors are hinged or track-mounted as shown on Fig. 3-44 and easily opened or closed by one man. The doors on the B-2707 are advanced derivations of the type used on the Model 707/727 airplanes and incorporate structural, mechanical and seal features to serve high temperatures and pressure differential requirements. Positive lock indication of the access doors is provided mechanically by the door handle position and is electrically displayed on the pilot's panel. All seals and seal retainers on doors and door openings can be replaced without requirement to remove the door. Adjustment is provided to assure door flushness with body contour.

b. The environmental control subsystem components are located in large well lighted equipment bays in the horizontal stabilizer leading edge (Fig. 3-45). Access is gained thru hinged doors equipped with minimal number of quick release type fasteners. No special tools are required for opening or closing of panels. Access is sized to permit replacement of the air conditioning pack as a modular unit or replace any component thereof. Smaller hinged access doors equipped with quick opening fasteners are provided to facilitate inspection and air cycle machine oil servicing without requirement to open large access panels.

The inboard ADS installations (located in the lower aft fuselage) and the outboard installations (located in the horizontal stabilizer) are accessible from underneath through double hinged doors. (Fig. 3-45) These doors are quick opening, incorporating a holding device to ensure door security when open. When open, a well lighted area of approximately 25 sq. ft. is available providing ample working space for two men.

The accessory drive bays are conditioned by air from the intrawall discharge ducts. After circulating through the compartment, the air is exhausted through an overboard discharge port. Thermal insulation is applied to the hot bleed ducts and portions of the walls.

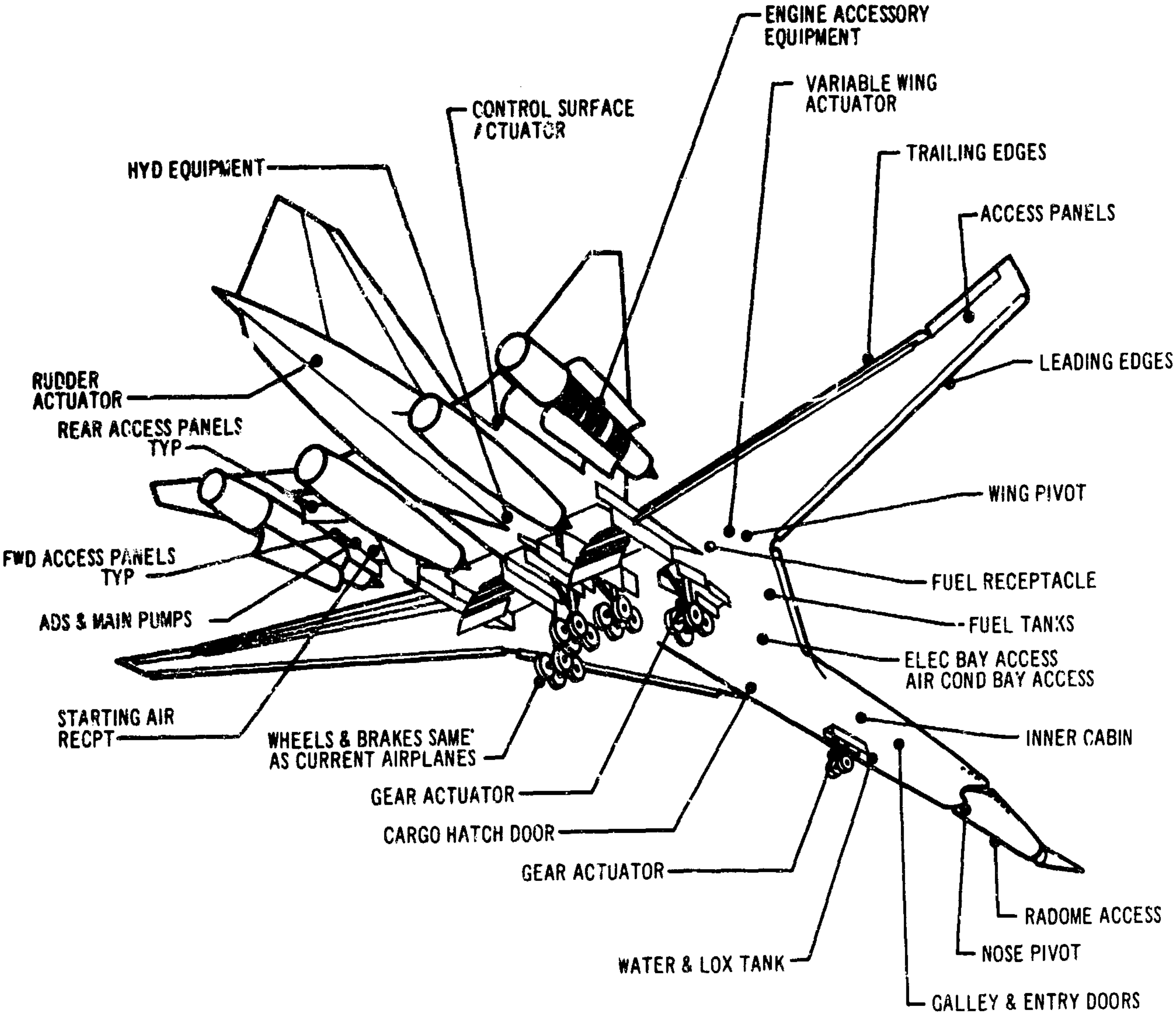


Figure 3-43. Access Provisions

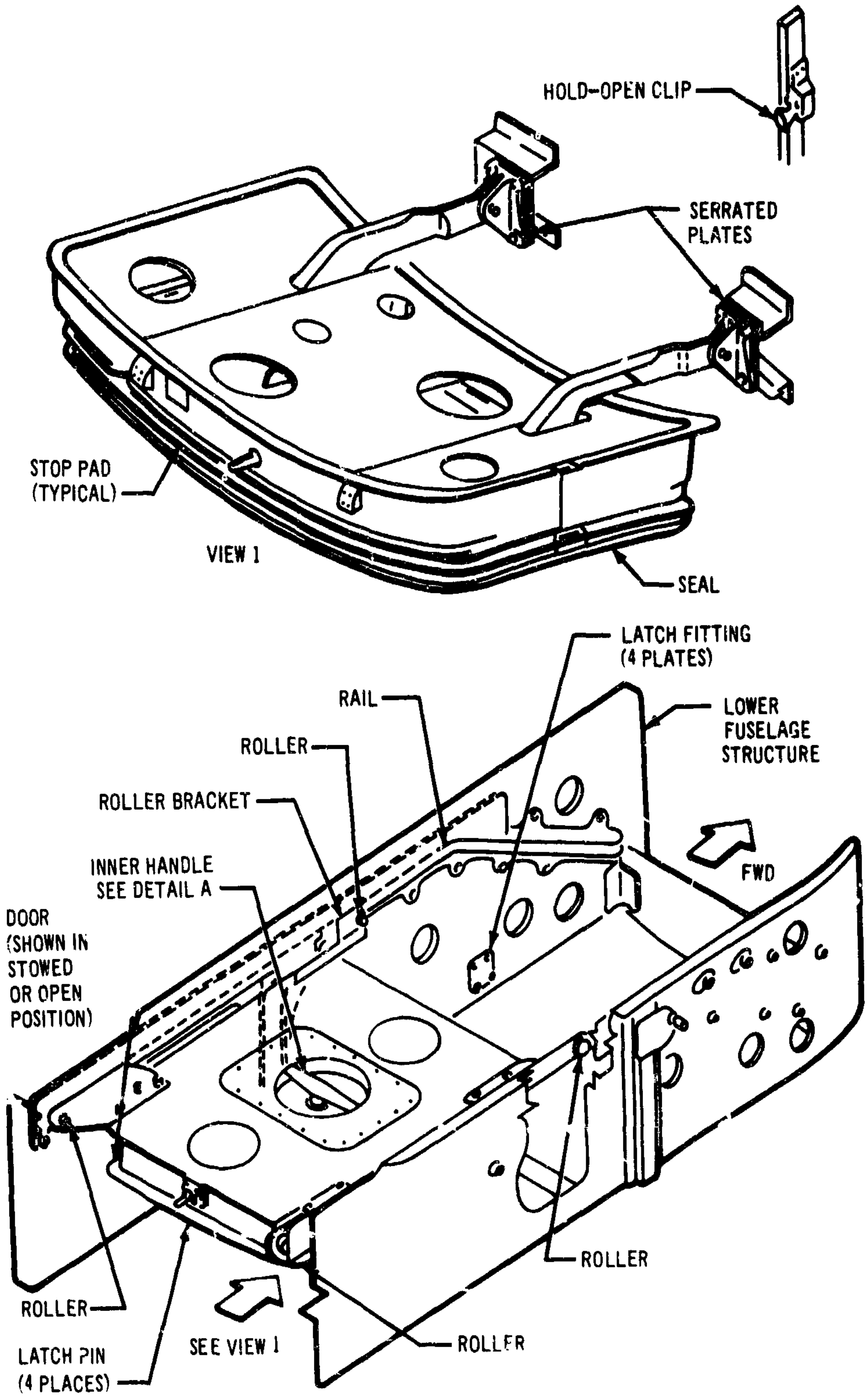


Figure 3-44. Plug-Type Access Doors

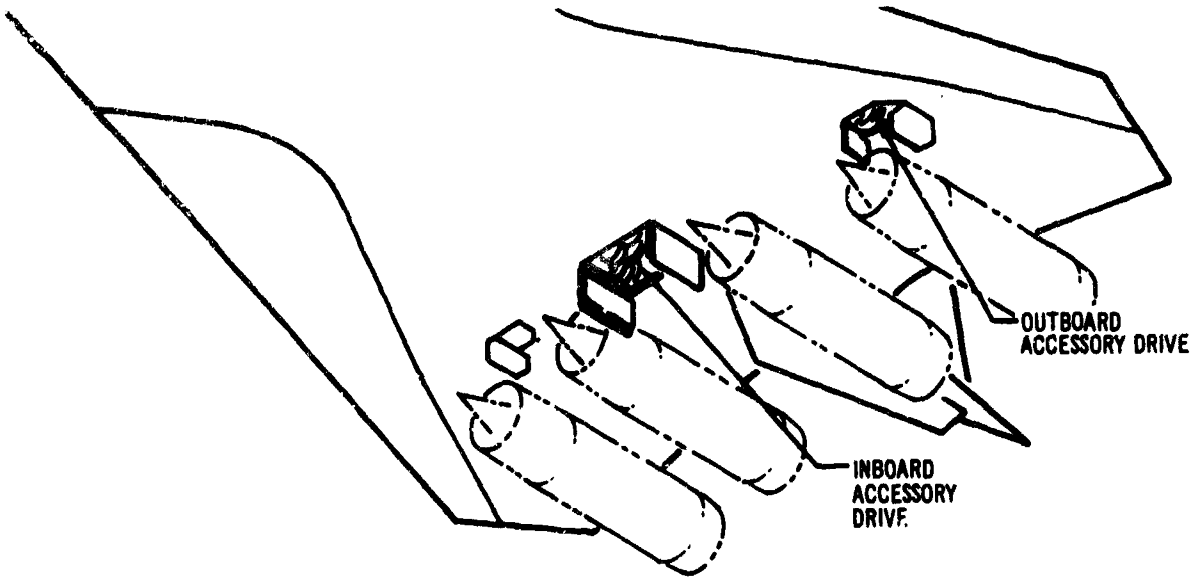


Figure 3-45. Accessory Drive Access

c. The engine side cowl panels are three-piece, interchangeable, and non-structural in design. See Fig. 3-46. A minimal number of quick-opening fasteners are incorporated in the panels. Special tools are not required to open or close the fasteners. The panels weigh approximately 110 lbs each, and are easily operated by one or removed by two men. Cowl supports are

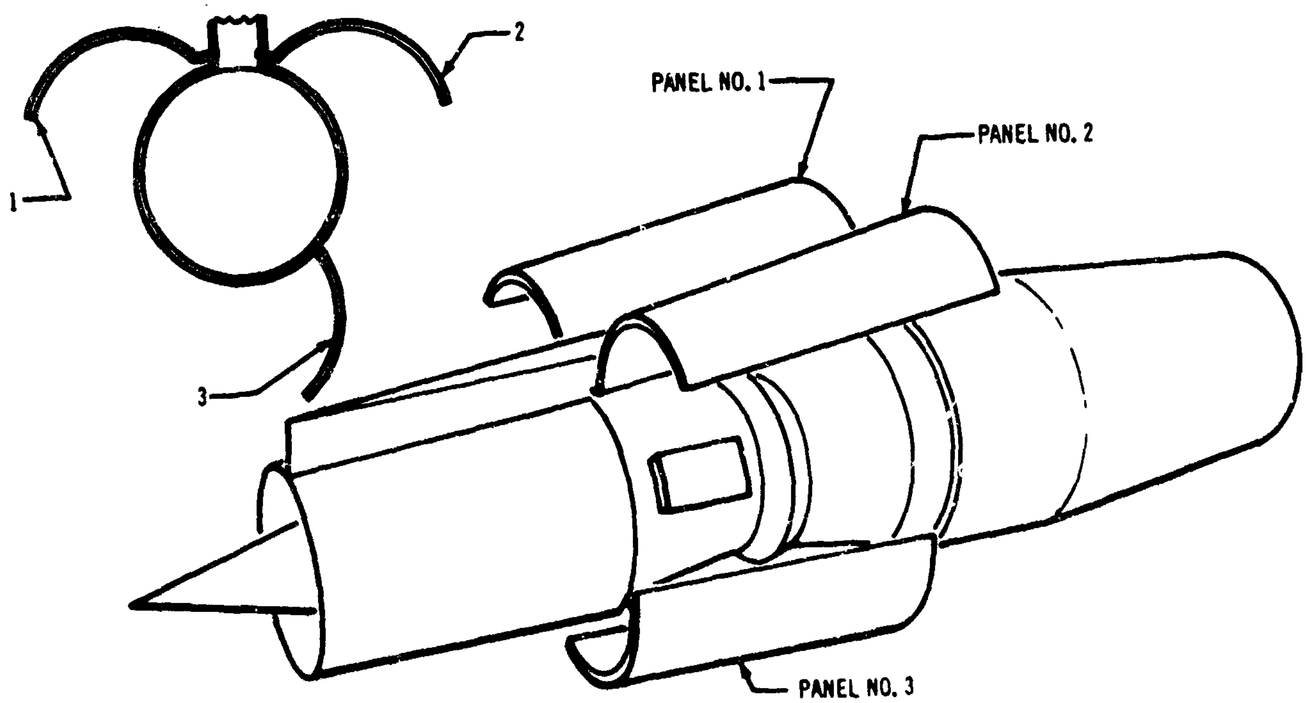


Figure 3-46. Engine Access Panels

incorporated as an integral part of each panel to hold cowling in the open position to facilitate maintainance and/or ground fire extinguishing. Removal is easily accomplished by rotating the panels 72 degrees and disengaging panel hinges. The design of the panels provides for full access to engine periphery to perform "on-condition" maintenance or facilitate engine change. Suitable markings are provided on cowling to identify servicing or inspection access and hazardous areas.

Access panels, hinged, non-structural in design, equipped with easy opening fasteners that can be opened by a gloved hand are provided for gaining access to areas requiring manual servicing or frequent inspection such as fuel and oil filters, engine oil tanks and pressure servicing points. Relief panels in the cowling protect against over-pressure and over temperature.

d. The nose and main landing gear door actuation systems incorporate a manual safety valve to allow manual opening of the doors providing ground service access to the wheel well areas. See Figs. 3-47 and 3-48. This provides unrestricted access to landing gear and brake hydraulics, wing sweep power drive unit, the three wing flap power drive units, wing sweep-flap programmer, and the ram air turbine (GE engine configuration only). Access provisions for inflight inspection of the landing gear locks in both the retracted and extended gear positions are provided.

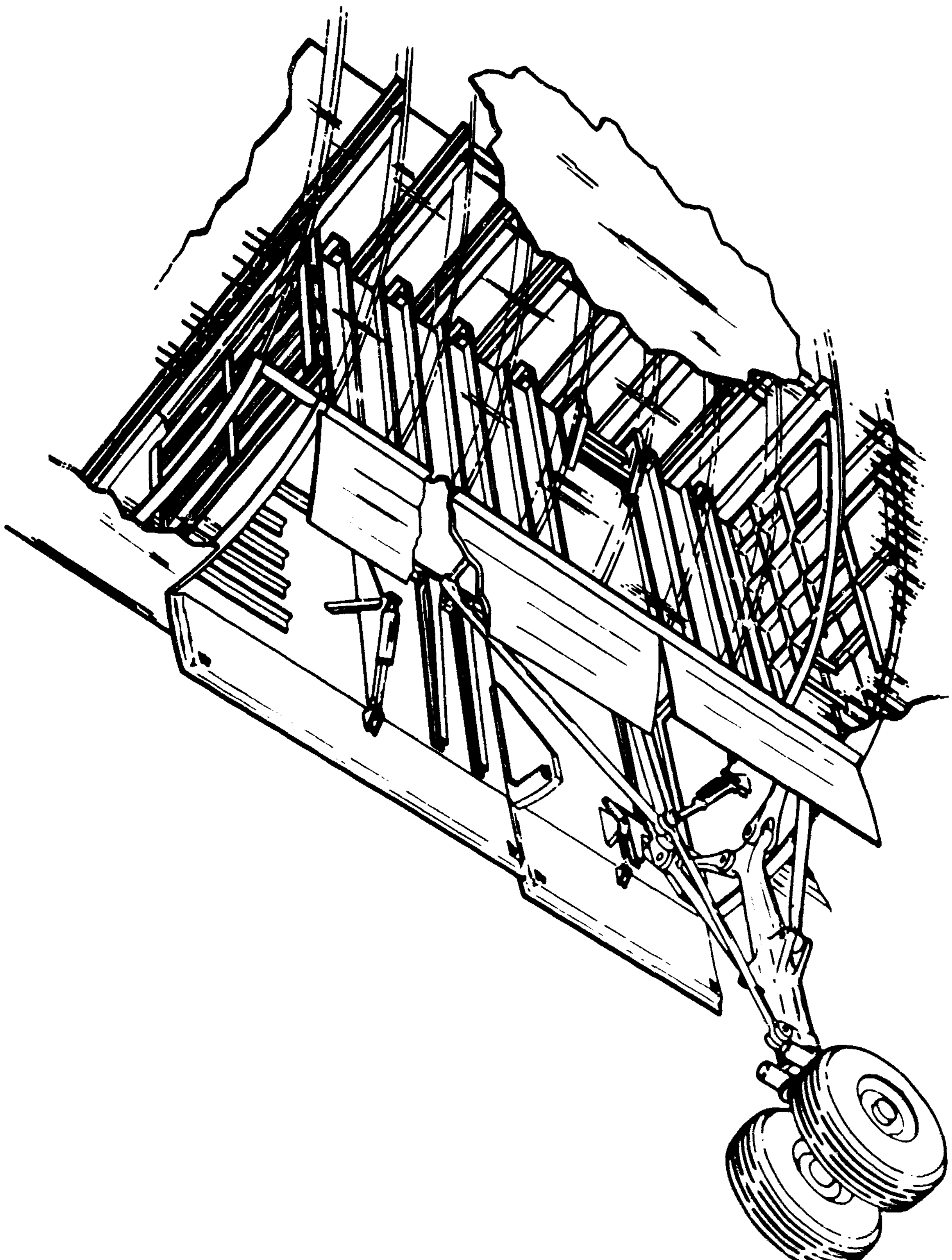


Figure 3-47. Nose Wheel Well Access

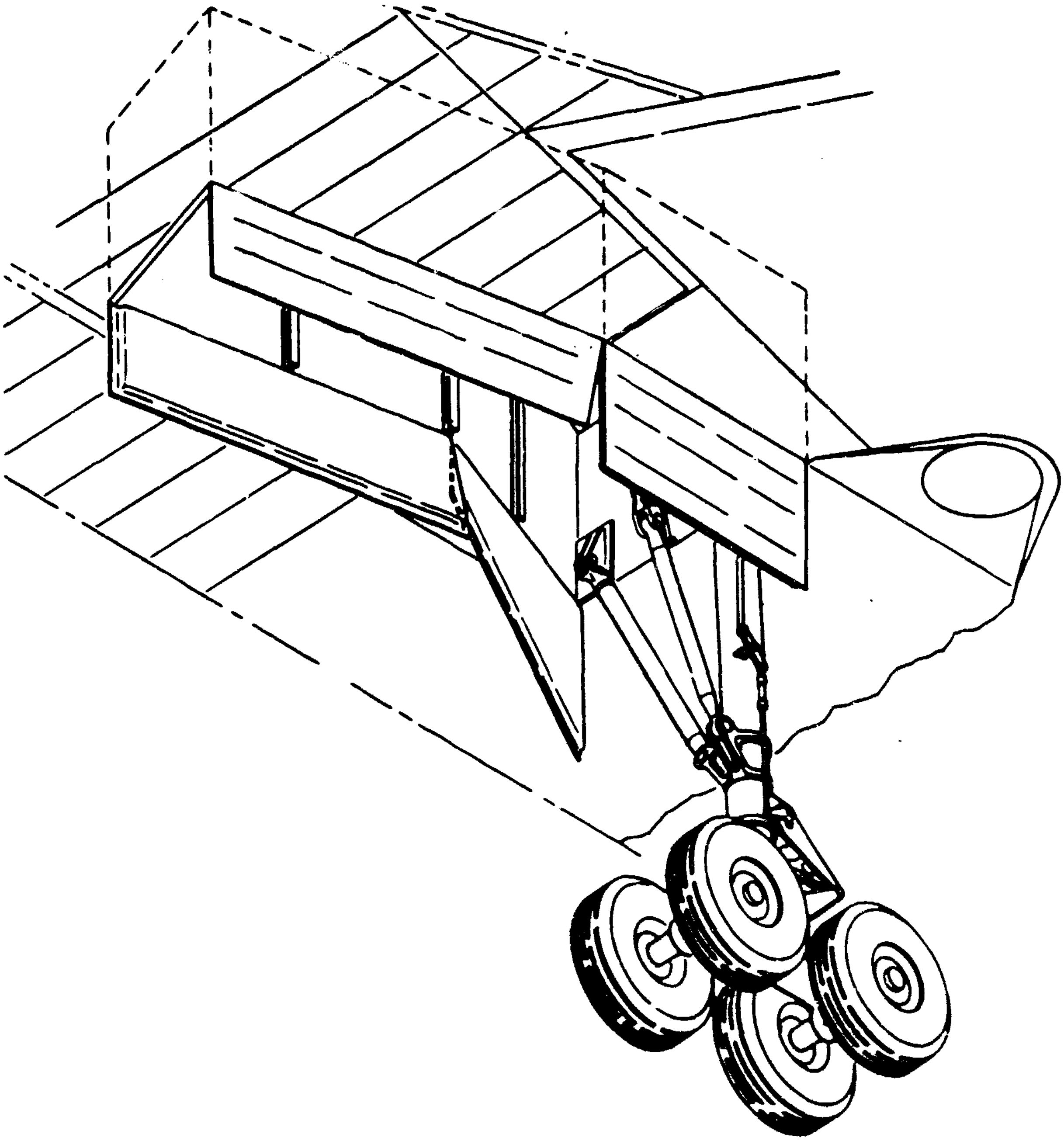


Figure 3-48. Main Gear Well Access

The nose wheel well is conditioned by air from the lower forward compartment. Air is directed on the tires and then exhausted through an overboard discharge port. Thermal insulation is applied to the wheel well doors and portions of the sidewalls.

The main wheel wells are conditioned by air from the intrawall discharge ducts. Air is directed on the tires and brakes and then exhausted through an overboard discharge port. Thermal insulation is applied to the wheel well doors and portions of the sidewalls.

e. Natural openings are used to best advantage in providing access to flight equipment. Extension of wing slats and flaps exposes subsystem components installed on the front and rear spars. The front spar mounted components

include slat drive torque tubes, ball screw actuators, slat position and asymmetry sensors and the forward auxiliary fuel tank selection valves. The rear spar mounted components include flap drive torque tubes, ball screw actuators, flap position and asymmetry sensors, spoiler and aileron cables, hydraulic lines, and the spoiler lock-out mechanisms.

Access to the spoiler power control packages is gained by raising the spoilers on the upper wing. The wing sweep power drive units, inboard and outboard wing flap power drive units, the wing sweep-flap programmer, and the ram air turbine (CZ engine configuration only) are mounted in the aft wheel wells and are readily accessible without removing access doors.

Non-structural doors provide access to elevon, elevator, rudder and aileron power control packages.

f. Hinged access panels equipped with quick release latches provide rapid access for servicing the waste tanks, for fueling, and for providing external electrical power, external air conditioning and pneumatic low pressure air. These access points are spaced along the underside of the aircraft to eliminate interference between servicing functions so that total servicing time is minimized. Access for both servicing and maintenance of the potable water and crew oxygen systems is through a quick-opening door to the forward equipment bay providing access to servicing panels, system controls and major components.

g. Visual inspection of the inlet and the front face of the engine can be accomplished through the cowl lip with the centerbody in the retracted position. More detailed inspection of the compressor stator vanes is accomplished by disconnecting actuator arms from inlet upper and lower air by-pass doors and performing a look-inspection through the gained access.

Access to the front face of the engine for on-condition maintenance to compressor stator vanes is accomplished by removal of the inlet. The inlet is attached to the engine face by eight bolts which are accessible once the engine side cowl panels have been opened. Inlet removal requires the universal engine change bootstrap kit to support inlet, removal of eight bolts, disconnecting two hydraulic lines, electrical connection, the anti-icing and cabin ram air ducts. Inlet can be disconnected, removed and re-installed in 20 minutes once the engine bootstrap change kit is in place.

h. Aerodynamic fairings cover and seal both the upper and lower wing pivot areas. Each lower fairing has a man-sized access panel (see Fig. 3-49) with quick-release fasteners to provide access directly into the wing pivot cavity allowing inspection and maintenance to fuel lines, hydraulic lines and flight controls.

i. Electronic systems components are located in the right hand and left hand walk-in equipment bays aft of the flight deck. Quick disconnect rack-mounted components are incorporated in all systems. A roll-out shelf concept with interconnect boxes is used for the electronic racks. This allows ready access to plugs and cables. The ATR's have built-in test equipment on the front panels.

j. Main electric system components are located in the right hand and left hand walk-in equipment bays forward of the aft cargo compartment. Standby electric system components are located in the right hand forward electronic equipment bay aft of the flight deck. Integral fault isolation capability, with display on annunciator panels, is incorporated in the electrical system. Additional fault isolation and circuit test capability is provided by test points at the circuit interface boxes, lighting, intercommunication receptacles and electrical power receptacles.

Cooling of the electric/electronic equipment in the forward and aft racks is accomplished by drawing cabin intrawall exhaust air through the equipment. During operation with the cabin to ambient pressure greater than approximately 3 psi, blowers are used to draw sufficient airflow through the equipment to overboard exhausts. The forward rack has a single blower and the aft rack has four blowers, one for each set of electric power conversion equipment.

In the event of a failure which results in closure of both intrawall valves, sufficient cooling is maintained in flight by utilizing the blowers. During this condition, the coolant air is exhausted into the lower forward compartment and under the aft cargo compartment floor. A low flow detector is provided in each rack. A warning light on the flight engineer's panel is activated by a signal from the detector when insufficient flow is provided.

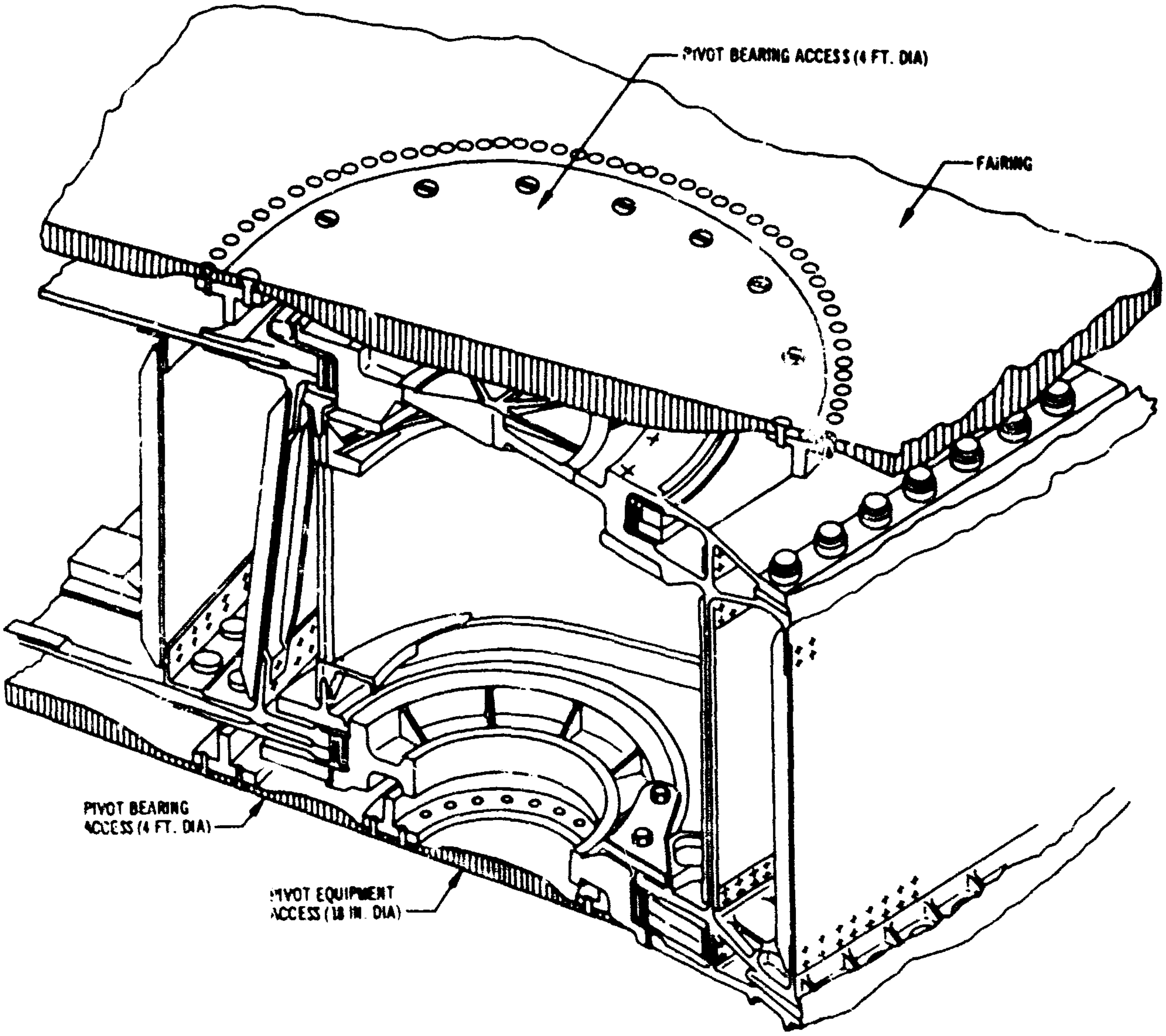


Figure 3-49. Wing Pivot Access

The weather radar compartment is cooled by cabin intrawall exhaust air.

k. The service and access provisions for the hydraulic power system have been planned to permit maintenance to be accomplished with much greater ease than is possible in present day subsonic jet aircraft. All components of the hydraulic power system, with the exception of the ADS driven pumps and pump associated components, are located in the hydraulic equipment bay. Access to the hydraulic equipment bay is provided through two large easily opened hinged doors (Fig. 3-45) on the lower centerline of the aircraft fuselage which when opened provide clear access to all the hydraulic power system components located in the bay. All service connections for the three main hydraulic power systems and the standby hydraulic power system are located within the hydraulic equipment bay. These service connections are readily accessible, protected from the external environment of the aircraft exterior, and closely located to instruments indicating the need for and extent of accomplishment of system servicing.

The ADS driven pumps and the components associated with these pumps are located within the four ADS equipment bays, which are accessible with ample space for trouble shooting, repair, or replacement of all hydraulic power system components mounted within these ADS equipment bays.

1. Fueling stations are located on the outboard lower side of wing strakes to permit simultaneous fueling, passenger and cargo loading and unloading, galley, water and waste servicing, and positioning of ground electric, air conditioning and starting equipment. The fueling stations locations are such that multiple use of fueling equipment will not interfere with other transient servicing or ground support equipment. See Fig. 3-50. The refueling station provides an illuminated ground refueling panel with system control switches, interphone jack and a set of repeater quantity gages. The access door to the panel is hinged and incorporates quick-opening fasteners. The access panel cannot be closed and latched until all system control switches are correctly positioned.

3.13 SPECIFICATIONS

A comprehensive set of specifications has been prepared for the B-2707 airplane as defined below and shown in Fig. 3-51.

The definition of the B-2707 airplane is contained in D6-17850, Model Specification.

Discrete differences between the production and the type designs are defined in Supplement I which also identifies the prototype subsystem specifications.

A series of subsystem specifications identifies the output performance of each subsystem; its interfaces with other subsystems; the basic design approach; and the subsystem test requirements. Where necessary, supplements to these specifications identify proposed production airplane differences.

Single page Requirements Specifications have been prepared for each item of ground support equipment necessary for the service, maintenance and

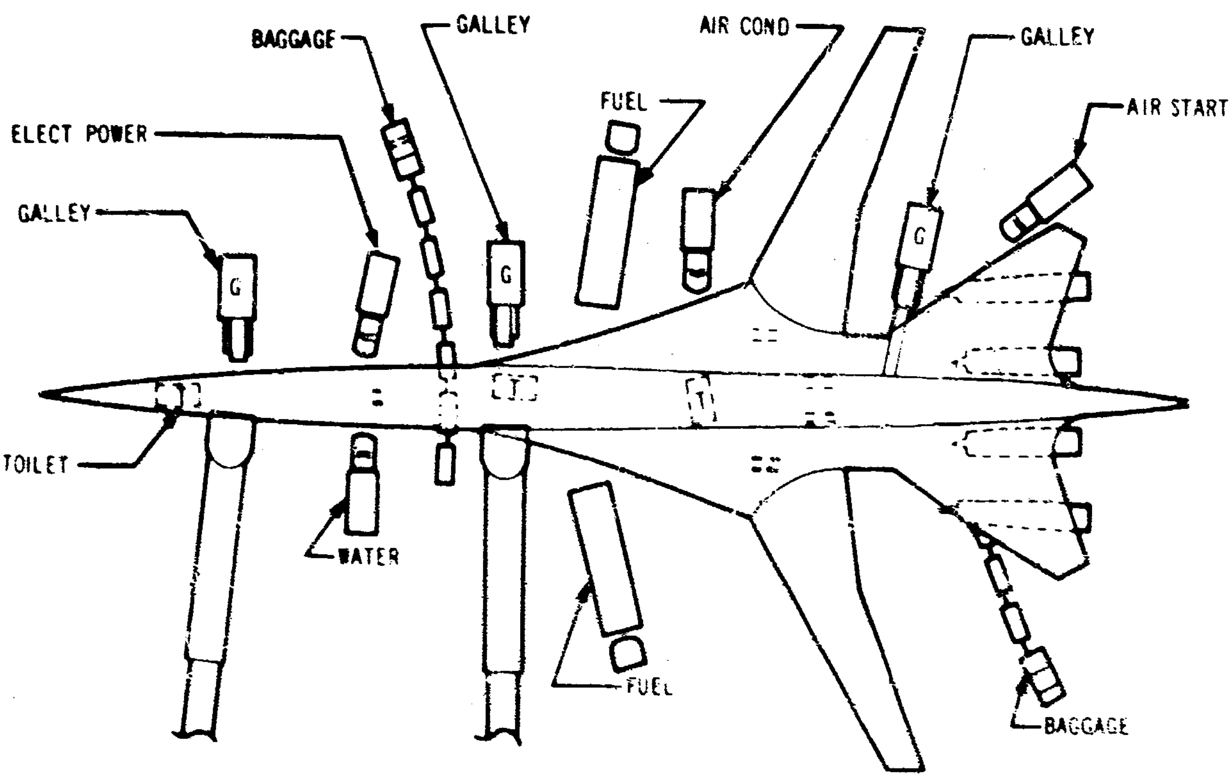


Figure 3-50. Servicing Arrangement

handling of the B-2707. A complete listing of these specifications is contained in D6A10180-1, "Ground Support Equipment Specifications."

A general requirements specification for the B-2707 training flight simulator, and a detailed performance specification for the training aids required to support training for the prototype, are included in D6A10181, "Training Equipment Specifications." The Training Flight Simulator specification will be completed during Phase III to allow design, development, test, and fabrication of a production simulator during Phase IV.

Specifications for the Flight Manual, Operations Manual, and Maintenance Manual for the prototype are submitted in "Technical Publications Specifications," D6A10182-1. The Flight Manual and Operations Manual specifications for the B-2707 will be developed during Phase III.

Specification for Manufacturers' Technical Data, ATA Specification No. 100, will be the standard for preparing the production B-2707 Maintenance Manual, Wiring Diagram Manual, Structural Repair Manual, Illustrated Tool Parts Catalog, Overhaul Manual, Tool and Equipment lists, Service Bulletins, Weight and Balance Manual, and all supplementary manuals, such as the Non-Destructive Testing Manual, Ground Support Equipment Manuals, and Training Equipment Manuals.

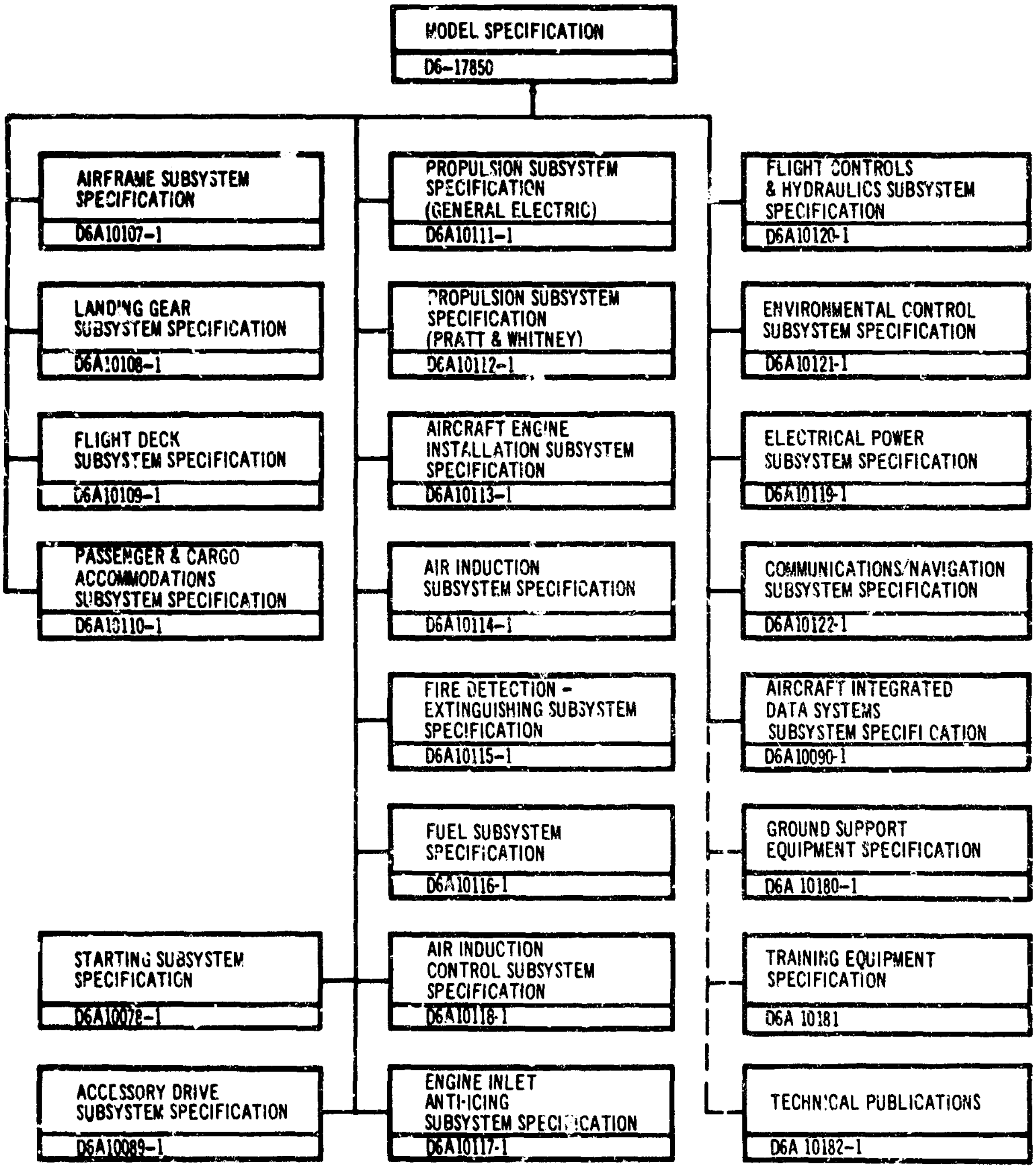


Figure 3-51. Specification Tree

CONTENTS

4.0 DESIGN INTEGRATION

The high standard of safety, performance and economics achievable with the B-2707 is directly related to the manner in which key design features have been integrated into a total system design.

The B-2707 has resulted from a series of design iterations. Design integration was a fundamental part in each iteration.

This program has culminated in an efficient configuration with validated technical competency sufficient to proceed with prototype construction. This section of the report has been arranged to present a discussion of the major integration aspects associated with its evolution. Material presented includes significant design choices, and associated trade data.

4.1 WING

4.1.1 Integrated Wing-Tail

The Boeing Model 733-290 (Fig. 4-1) which was proposed to the FAA in November of 1964 was a variable sweep arrow wing design with a separate horizontal tail. The airplane had excellent characteristics even though the wing was somewhat thicker (in percent chord) than was desired from an aerodynamic standpoint. Subsequent testing in preparation for prototype detail design indicated that the jet exhaust plume was bending at supersonic speeds and could cause appreciable structural heating of the horizontal tail (Fig. 4-2). The data taken with four kerosene-oxygen burners simulating the jet engines show that flight maneuvers outside the range of ±0.5g would cause temperatures in excess of 1,500°F over the tail.

Subsequent testing indicated that no position above the vertical location of the 733-290 tail would have satisfactory longitudinal stability characteristics. It was then determined that a position close to the trailing edge of the wing, but still above the wing chord plane, would be satisfactory providing the outboard engines were moved out on the wing far enough for the exhaust plumes to clear the horizontal tail laterally. This major design change moved the wing pivot far outboard, brought the horizontal tail close to the wing, and appreciably increased the fixed (highly swept) portion of the wing. The Model 733-414 (Fig. 4-3) exemplifies this type design. Several serious problems were evident. The longitudinal stability and the outboard engine-out control were marginal, and all low speed and subsonic characteristics had deteriorated below the satisfactory levels because the wing span had decreased to about 145 ft. Designs were pursued to achieve the wing span deemed necessary to make a satisfactory airline airplane and to improve the overall stability and control characteristics. An intensive wind tunnel testing program showed that a large horizontal tail mounted close to the wing had several attractive features. Fig. 4-4 shows a wind tunnel model of this configuration. The aerodynamic center for all regimes of flight was far to the rear, and the longitudinal stability was excellent. However, the drag and structural weight of the separate wing and tail were high and the problems of exhaust gas heating of the tail and sonic fatigue had not been solved.

Inasmuch as the tail and wing were in close proximity it was decided to try to integrate them for the supersonic flight condition. This approach was tested in the wind tunnel. When the wing and tail were designed as a single unit for supersonic flight but not physically connected, there is a small drag penalty. This small penalty, however, is more than overcome by the large increases in structural depth at the wing rear spar and horizontal tail front spar (Fig. 4-5). Depth and stiffness increases in both the wing and tail resulted in significant reductions in unit weights. The wing thickness ratio has decreased from 4.5 percent at the pivot and 4.0 percent at the side of the body, to a constant 2.8 percent over the entire wing. Broadly speaking, the wing box and wing pivot depth have increased 50 percent, the wing stiffness has increased 50 percent, and the tail stiffness has increased 300 percent. Because of the increased depth of the wing box, the stiffness of the landing gear attachments at the front and rear spars is also improved. A large increase in fuel volume has been realized as a result of the increased wing thickness. This, in turn, has made it practical to increase the payload-range capabilities of the aircraft.

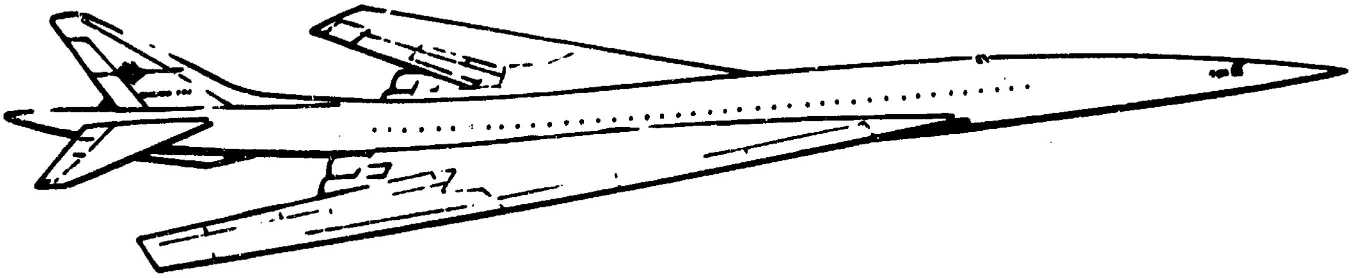


Figure 4-1. Boeing Model 733-290

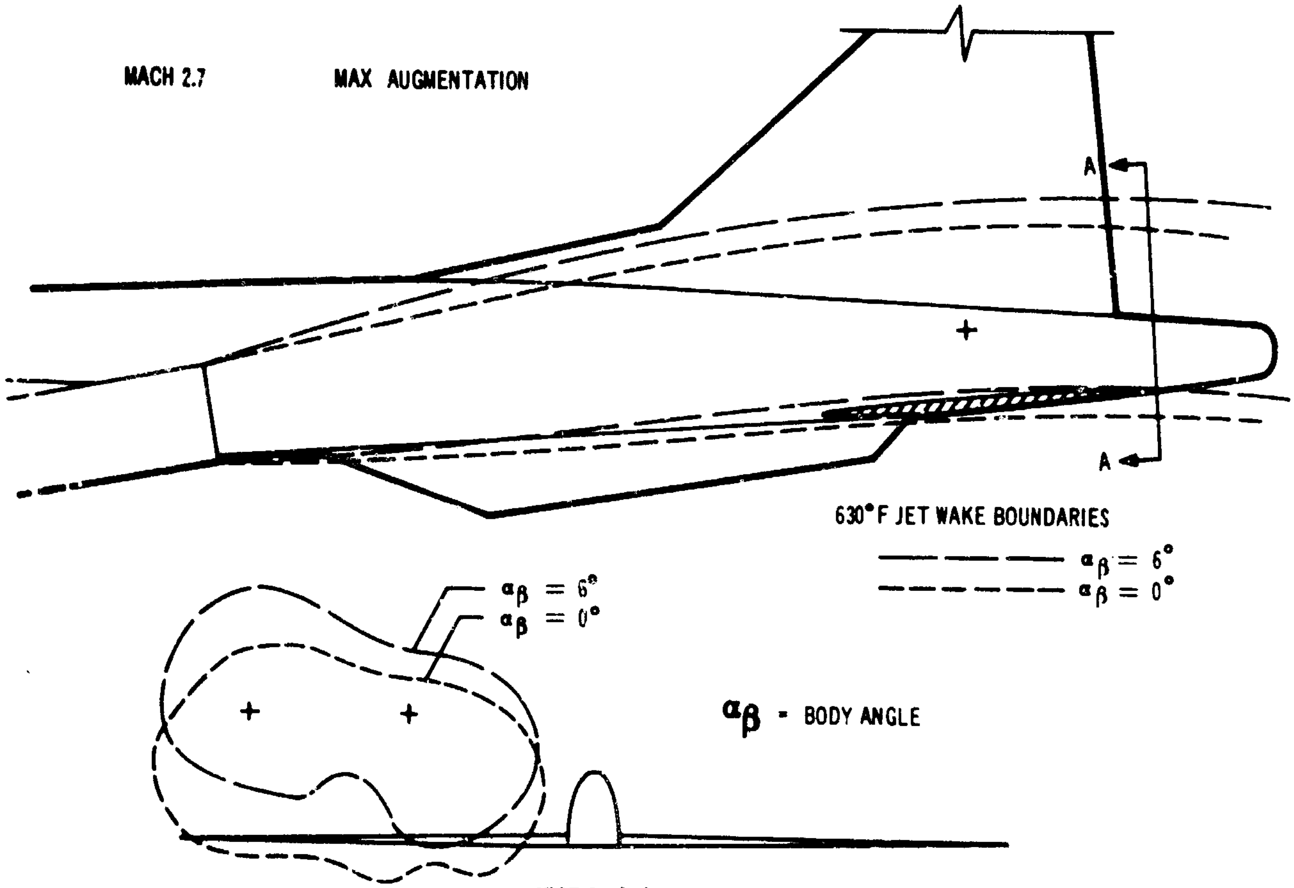


Figure 4-2. Horizontal Tail Heating

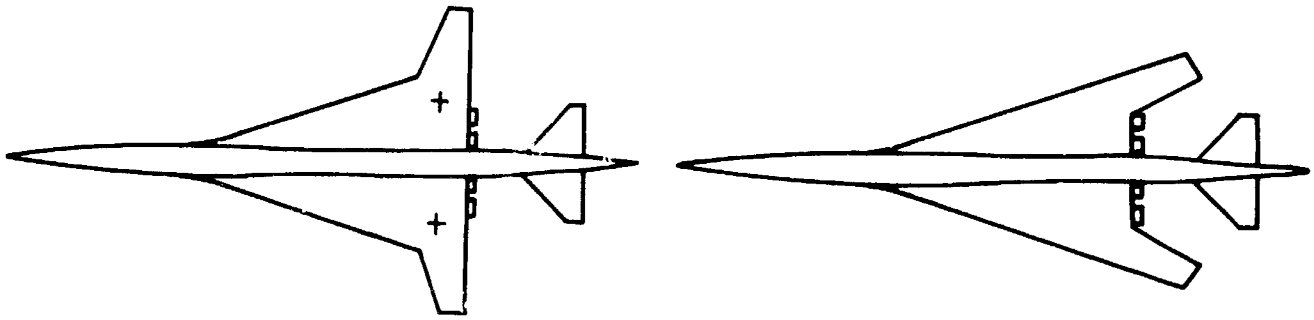


Figure 4–3. Boeing Model 733–414

Figure 4–4. Large Tail Configuration

For satisfactory engine operation, it is necessary that airflow characteristics entering the inlet be virtually constant across the inlet face. Because of the proximity of the inlet face (of the outboard pod particularly) and the wing trailing edge-horizontal tail leading edge juncture, elimination of any aerodynamic disturbances attributable to the juncture has been achieved by a shear connection between the wing and tail. (Fig. 4-6). The shear connection prevents any lower wing-tail surface discontinuities resulting from either positive or negative wing bending relative to the

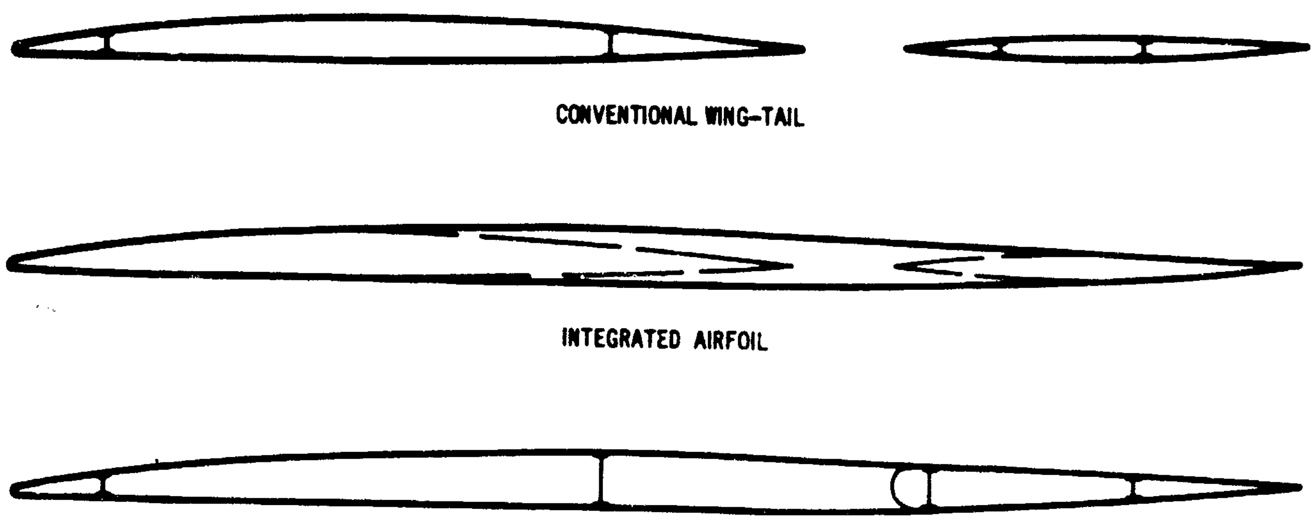


Figure 4-5. Airfoil Concept

horizontal tail. It also permits the wing and tail to function as a smooth and continuous airfoil, thus enhancing the aircraft's aerodynamic efficiency.

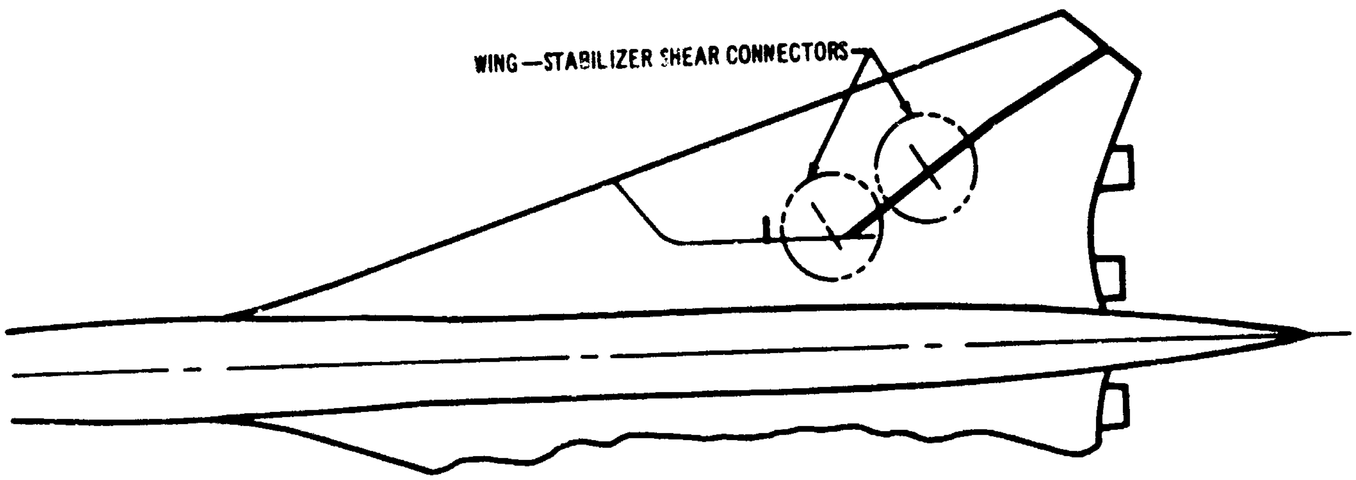
The resulting stability and aerodynamic center locations have allowed the engines to be integrated into the horizontal tail structure and the problems of sonic fatigue and exhaust heating have been eliminated. Also the location of the engines allows large span trailing edge flaps to be mounted on the wing. These large flaps improve the takeoff and landing characteristics and provide a means of protecting the engine inlets from water, slush, and other foreign objects.

Flap stowage space is conveniently provided in the trailing edge of the variable sweep wing because of the increased wing depth (relative to a more conventional wing-tail arrangement). The flaps also form the trailing edge closure for the variable sweep wing when the wing is in the extended (subsonic cruise) position (Fig. 3-12).

4.1.2 Pivot Location

The discussion on variable sweep has pointed out the advantages of large low speed wing spans for airline operations. The location of the pivot in the variable sweep wing is a compromise of several important factors. An inboard location at the side of the body would result in maximum wing span but would also produce a large shift in aerodynamic center with wing sweep. The inboard location would also result in maximum wing and pivot weights since the bending moments would be high. An outboard location would result in a small wing span increase with wing sweep, light pivot weights, and an overbalance or rearward shift in aerodynamic center at low sweeps. The location of the pivot at 29.3 percent of the wings aft span is the result of intensive studies of all the factors including stability, aerodynamic efficiency, weight, and configuration of the landing gear. A comparison of the L/D_{max} for the B-2707 with current Boeing jet transports and some developmental models is shown in Fig. 4-7. The wing span produced by the chosen pivot location assures good low speed takeoff, landing, and noise characteristics.

The main landing gear is attached to the wing box-pivot structure. The fore and aft location of the pivot has been adjusted to allow the forward main gear to attach to the front spar and the rear



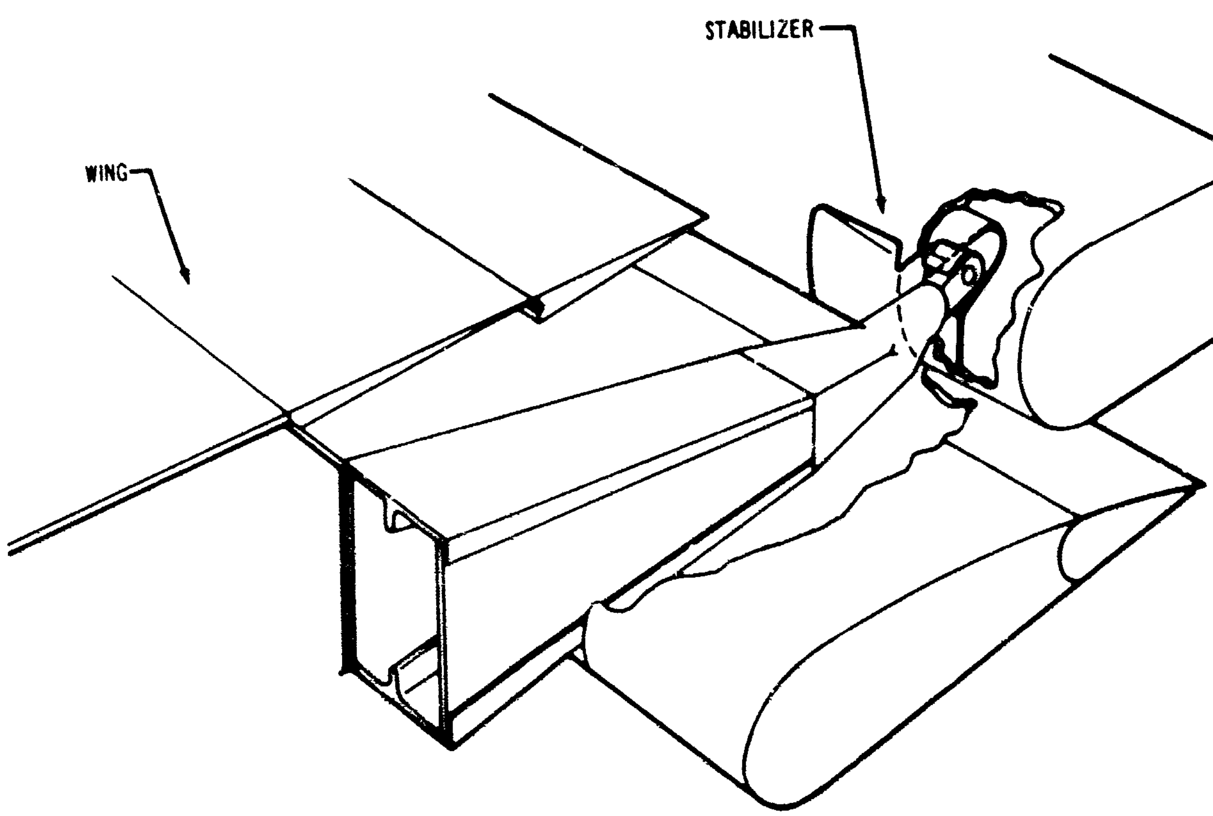


Figure 4-6 Typical Wing-Stabilizer Shear Connector

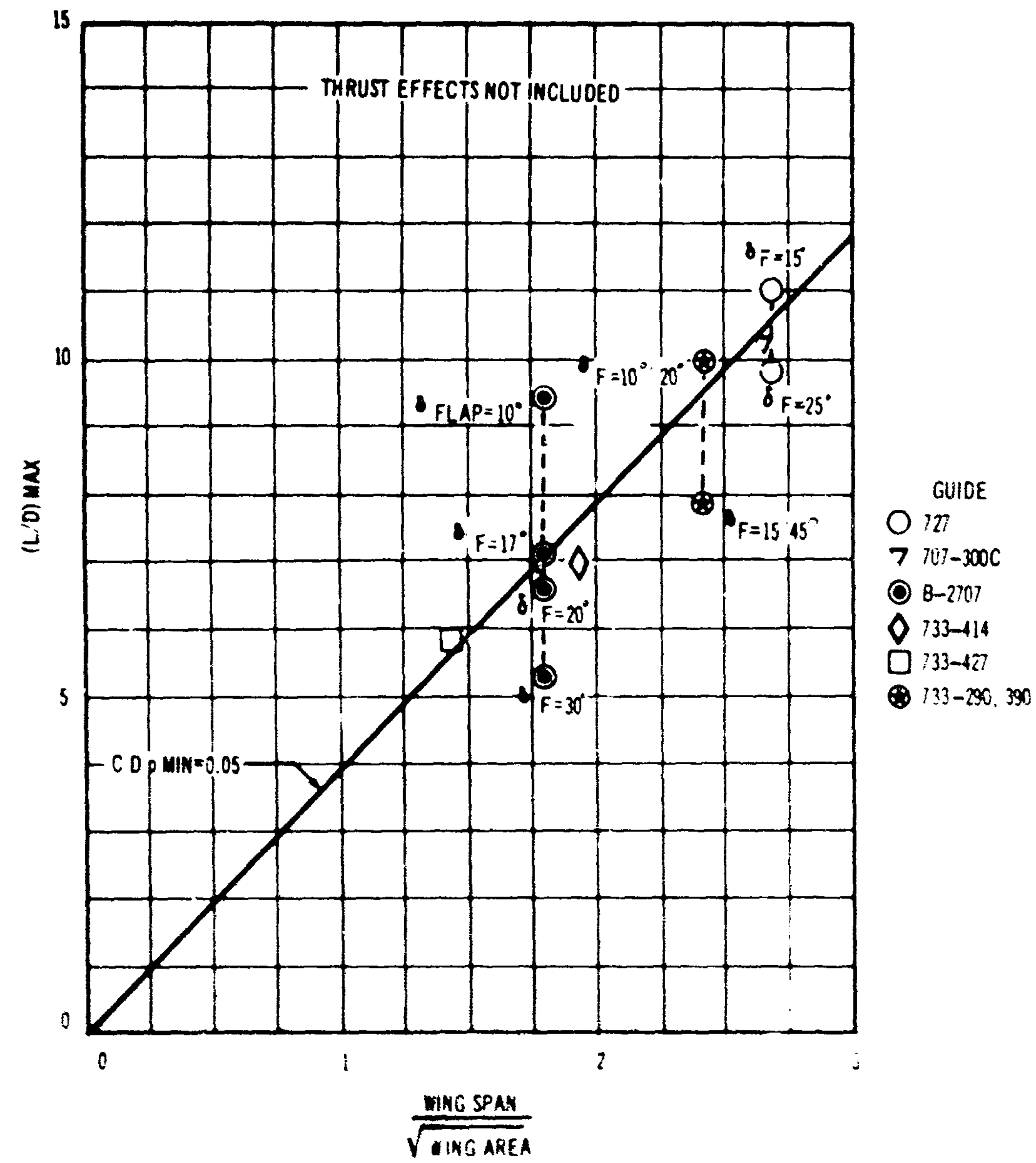


Figure 4-7. Takeoff Performance

main gear to attach to the rear spar. The attachment of the four main landing gear struts to the rugged wing box-pivot structure provides a minimum overall weight installation. Fig. 4-8 shows the relationship between the landing gear location and the wing pivot structure.

4.2 PROPULSION

Major design decisions in the propulsion area included the following:

4.2.1 Pod Location and Type

Potential engine pod locations are indicated in Fig. 4-9. Theory, practical considerations, and wind tunnel tests provide a basis for determining the relative desirability of these locations. Below-wing mounting is best and above-wing poorest from the standpoint of local Mach number at the pod inlet, with other locations ranking between these extremes. Below-wing locations which place the exhaust nozzle an appreciable distance forward of the wing trailing edge are impractical due to exhaust impingement and sonic effects on the aft wing structure. Placing the pod aft so that the nozzle extends beyond the wing trailing edge eliminates this problem.

Pod/wing tailoring for favorable interference effects is based on utilizing the pressure field which exists behind the pod bow shock and acts against the wing lower surface (Fig. 4-10). The positive pressure field produces a lift increment which would not be present if the pod were removed. Note that a negative pressure region is produced also. The pod and wing of Fig. 4-11 take advantage of the favorable factors and minimize those which are unfavorable. The fore and aft position of the pod was selected so that the point at which the pressure field changes from positive to negative occurs at the wing trailing edge. Thus, the negative pressure field cannot act on the wing and reduce the lift increment. The aft portion of the wing is reflexed so that at cruise attitude, the lower surface slopes in a direction which produces a forward (thrust) component from the pod pressure field. This thrust component cancels at least part of the nacelle drag. The lift increment on the wing permits flight at a slightly lower angle of attack, reducing induced drag. Thus, the beneficial effects are cumulative. Fig. 4-12 shows the general shape of the pod pressure fields, and hence the regions of the wing in which a favorable undersurface slope is desirable. Other factors are involved (see Aerodynamic Design Report V2-B2707-3), but this discussion covers the basic concepts of designing for favorable interference. Representative aerodynamic improvement due to pod wing tailoring is indicated in Fig. 4-13. The wind tunnel models, Fig. 4-14, are typical of those employed in the pod design and pod/wing integration development program.

Fig. 4-15 summarizes the factors which were considered during the B-2707 engine pod design and location studies. Fig. 4-16 outlines the design process from the aerodynamic standpoint. Most of these factors have been discussed or are self-explanatory. Those which require additional comment are covered in the following paragraphs.

The B-2707 engine pods and installation on the wing are shown in Figs. 4-17 (GE) and 4-18 (P&WA). Aerodynamic and exhaust impingement considerations required that the pods be located with inlets below the tail (aft wing) and nozzles extending aft of the trailing edge. Airplane balance was a primary factor limiting how far aft the pods could be placed. The selected nozzle position facilitates installation of the thrust reverser system. Reverser gases are directed both above and below the wing (Fig. 4-19) in such a manner as to avoid exhaust impingement on the airplane and exhaust gas/foreign object ingestion in the inlets. Airplane pitching moment change due to inflight thrust reversal is well within pilot and control system capability. The vertical location of the pods close to the wing was established by aerodynamics and the weight penalty for excessive landing gear length. Boat-tailed, diverter-mounted pods were selected rather than the simpler axisymmetric, strut-mounted type because of their advantages in these respects.

Spanwise locations were governed by the requirement for control surfaces of reasonable proportions and sufficient area within the limited trailing edge length available. Proximity of engine inlets (unstart) and inboard exhaust on the fuselage were important spanwise considerations also.

With approximate locations of the pods established in this manner, final positions of the pods and trailing edge were adjusted in an extensive series of design studies to optimize the tail primary structure, accessory drive system locations, and system safety characteristics in event of compressor/turbine disc failure.

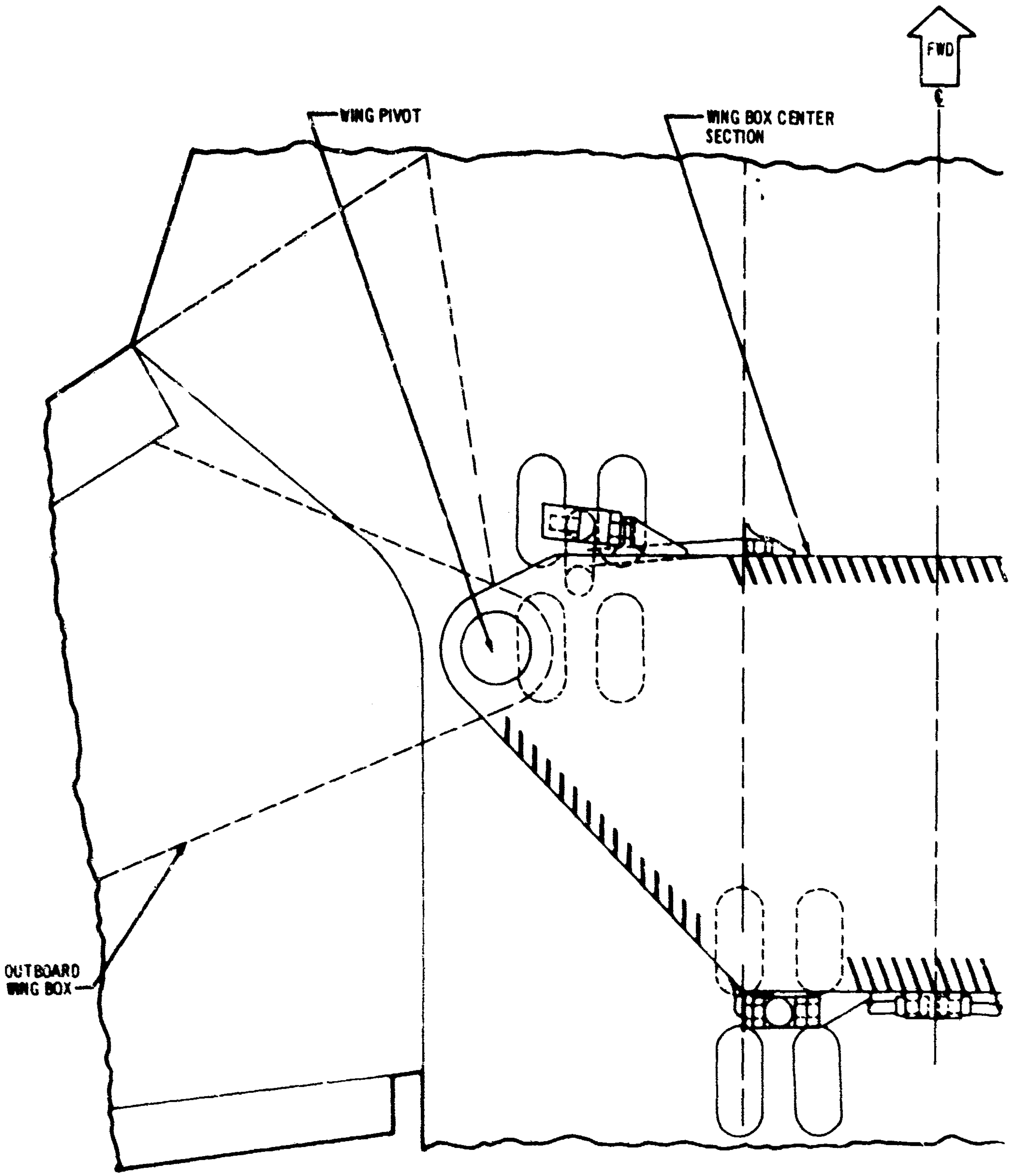


Figure 4-8. Pivot Structure and Gear Relationship

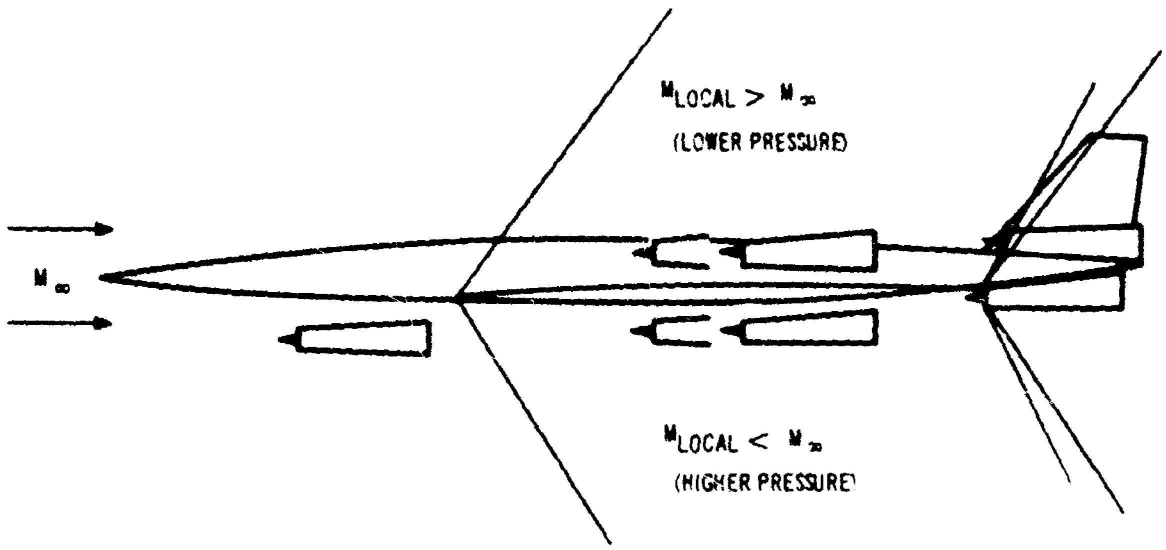


Figure 4-9. Possible Inlet Locations

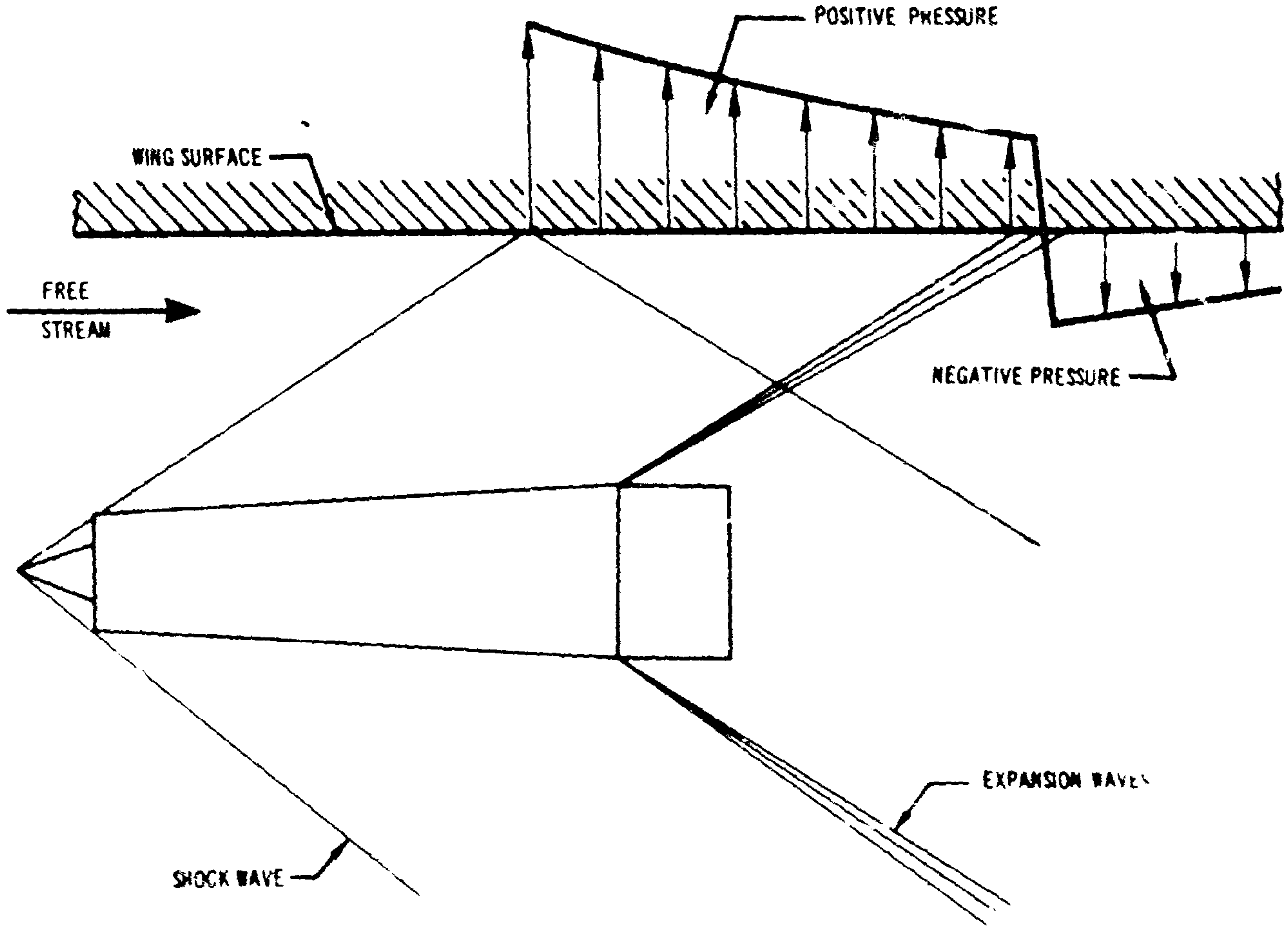


Figure 4-10. Interference Lift

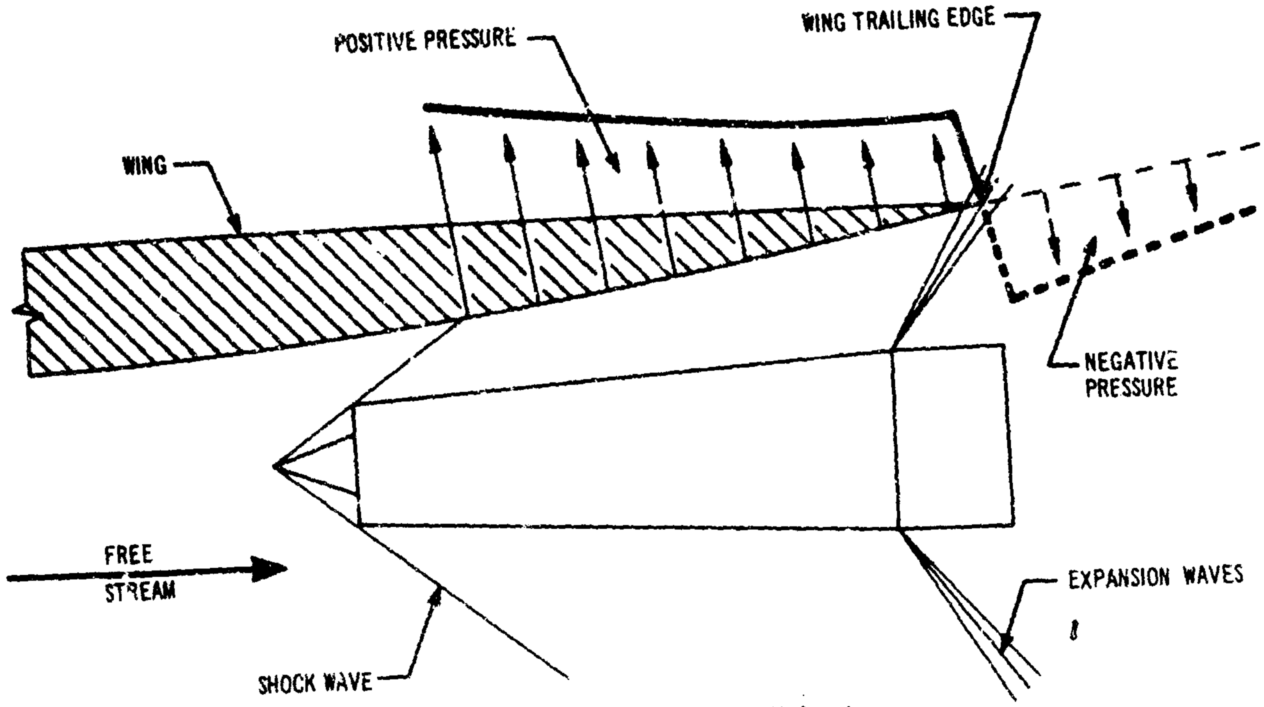


Figure 4-11. Interference Lift Utilization

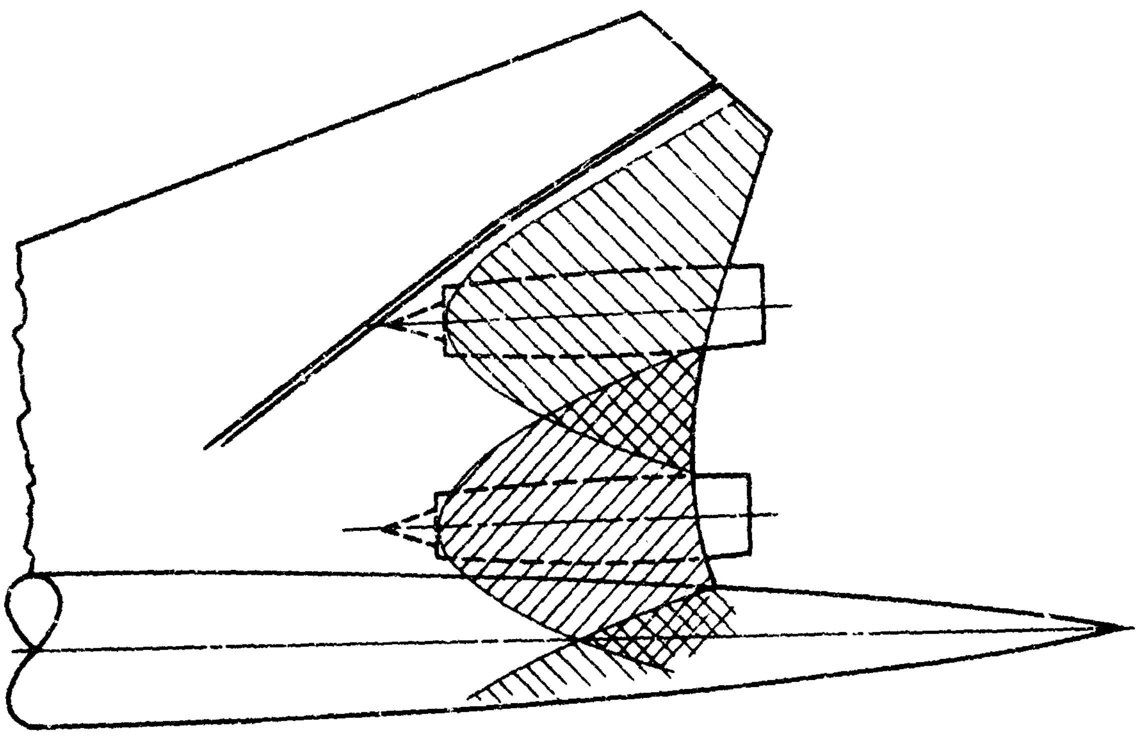


Figure 4-12. Pod Pressure Fields on Wing

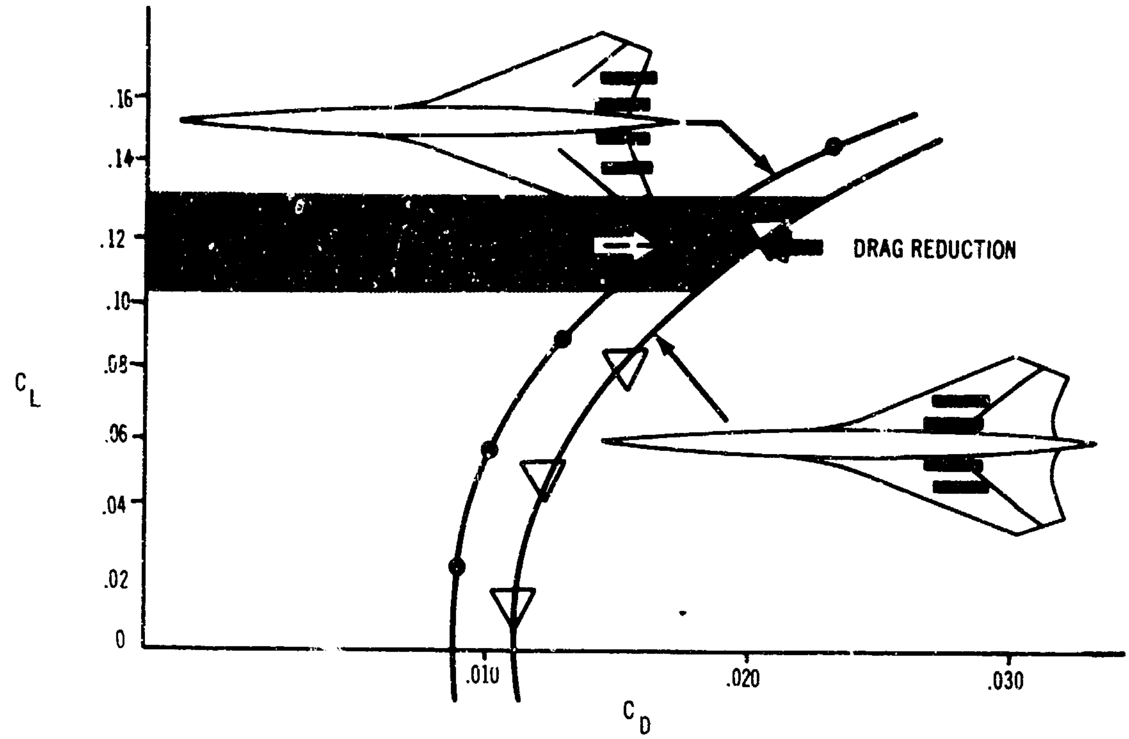
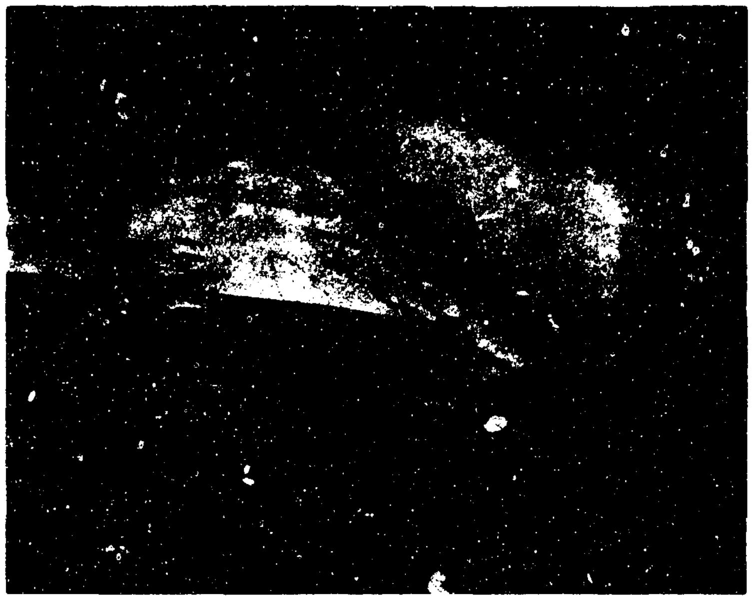


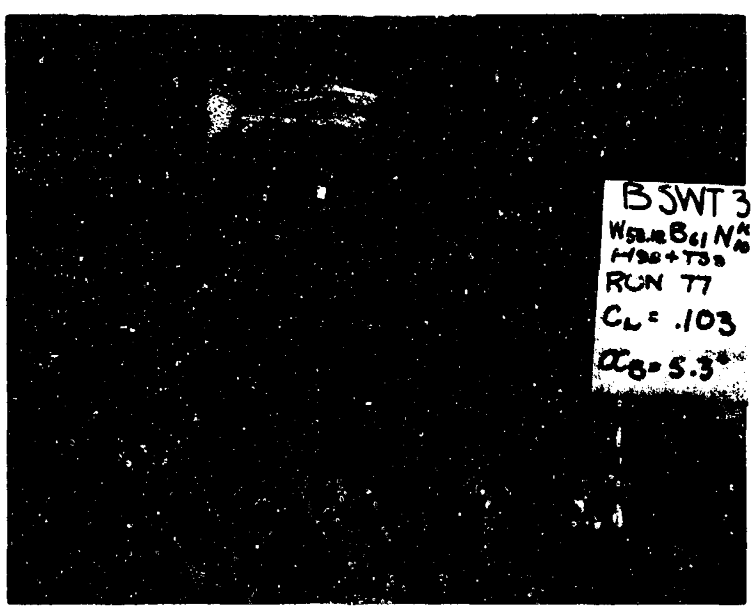
Figure 4-13. Aerodynamic Improvement with Pod/Wing Optimization

The pod/horizontal tail arrangements selected as a result of these studies are shown in Figs. 4-20 (GE) and 4-21 (P&WA). In both configurations, the pods are staggered slightly to minimize the possibility that disc fragments from a failed engine may damage the corresponding section of an adjacent engine. To the maximum practical extent, pods and critical components in the horizontal tail are positioned so that compressor/turbine discs are not aligned with primary structure, controls, hydraulic actuators and lines, fuel tanks and lines, and accessory drive systems and shafts. The structural, safety and equipment installation aspects of the horizontal tail and pods are under continuing review and study for further improvement.

The influence of the aft mounted engines on sonic boom can best be illustrated by considering the "near field" pressure wave generated by the airplane. Generally, a pressure wave consisting of several shock waves results in lower maximum overpressures than pressure waves which consist of only two. Hence, it is desirable to delay the joining up of the shock waves produced by the airplane. The shock wave pattern and resulting pressure wave at the ground for the B-2707 flying at Mach 1.3 and 42,000 ft altitude is shown in Fig. 4-22. This pressure wave consists of four shock waves, one of which emanates from the vicinity of the inlets. Theoretical calculations of the shock wave pattern generated at high altitudes and Mach numbers indicate that the shock wave emanating from the inlets does not join with either the front or rear shock waves. Thus, due to the aft location of the engines a multiple shock wave pattern is produced even at cuise with a resultant reduction in maximum overpressure. This pod location requires the basic wing design to be modified in the area of the nacelles. Fig. 4-23 illustrates the decrease in cruise drag associated with a properly modified wing trailing edge (reflexing). The upper curve represents the cruise drag of a basic wing with increasing amounts of trailing edge reflex with no pods under the wing. The lower curve is for the same reflexed wing in the presence of the pod pressure field. A substantial decrease in cruise drag is evident due to the favorable interference effects of the pressure field exerted by the pods on the lower surface of the reflexed wing.



(a) WIND TUNNEL MODEL



(b) OIL FLOW TEST

Figure 4-14. Pod Development Models

ITEM	OPTIMUM POD LOCATION ON WING		
	FORE AND AFT	SPANWISE	DISTANCE BELOW WING
1 MINIMUM DRAG – POD AND STRUT	AFT	NOT CRITICAL	CLOSE
2 FAVORABLE WING/POD INTERFERENCE	AFT	NOT CRITICAL	CLOSE
3 MINIMUM BOUNDARY LAYER THICKNESS (DICTATES STRUT OR DIVERTER HEIGHT AT INLET)	FWD	NOT CRITICAL	[3]
4 MINIMUM UNSTART PROBLEMS AND CONTROL DEVICES.	FWD: NO STAGGER	WIDE SPACING BETWEEN PODS	WELL BELOW
5 LOW MACH NUMBER AT INLET	AFT	INBOARD	CLOSE
6 MINIMUM YAW MOMENT (ENGINE OUT)	NOT CRITICAL	MINIMUM DISTANCE FROM AIRPLANE ℄	NOT CRITICAL
7 MINIMUM TRIM CHANGE (ENGINE THRUST VARIATIONS)	NOT CRITICAL	NOT CRITICAL	CLOSE
8 FOREIGN OBJECT INGESTION (MINIMIZE)	FWD	MAXIMUM SEPARATION FROM LANDING GEAR	CLOSE
9 EXHAUST IMPINGEMENT (MINIMIZE)	AFT	AWAY FROM BODY	NOT CRITICAL FOR NOZZLE AFT OF T.E.
10 SONIC EFFECTS (MINIMIZE)	AFT	AWAY FROM BODY	NOT CRITICAL FOR NOZZLE AFT OF T.E.
11 WING TORSION & FLUTTER	FWD	OUTBOARD	NOT CRITICAL
12 STRAIGHT-FWD WING STRUCTURE, CONTROL SURFACE ACTUATOR AND FUEL TANK ARRANGEMENT	FWD	NOT CRITICAL	NOT CRITICAL
13 SPACE ABOVE POD FOR ATTACHING STRUCTURE, DUCTS, ETC.	FWD	INBOARD	WELL BELOW
14 THRUST REVERSER DUCT THROUGH WING (MINIMUM LENGTH)	AFT	OUTBOARD	CLOSE
15 T.E. LENGTH AVAILABLE FOR CONTROL SURFACE (MAX)	NOT CRITICAL	[1]	NOT CRITICAL
16 ADS DRIVE SHAFT LENGTH (MINIMUM)	FWD	NOT CRITICAL	NOT CRITICAL
17 INLET BY-PASS DOOR (MINIMUM INTERFERENCE WITH WING)	NOT CRITICAL	NOT CRITICAL	WELL BELOW
18 BENDS IN ENGINE ℄ (MINIMUM)	FWD	NOT CRITICAL	WELL BELOW
19 MAINTAINABILITY	NOT CRITICAL	SPACE FOR HINGED COWL OPEN	WELL BELOW
20 LANDING GEAR LENGTH (MINIMUM)	FWD	NOT CRITICAL	NOZZLE CLOSE OR BURIED
21 SAFETY [2]	AFT AND STAGGERED	MAXIMUM SEPARATION POD/POD & POD/BODY	NOT CRITICAL
22 AIRPLANE BALANCE	FWD	NOT CRITICAL	NOT CRITICAL
23 WEIGHT (MINIMUM AIRPLANE OEW)	FWD	NOT CRITICAL	CLOSE

[1] AVOID CLOSE SPACING - POD/POD AND POD/FUSELAGE

[2] MINIMIZE CONSEQUENCES OF COMPRESSOR/TURBINE DISC FAILURES: WHEELS-UP LANDING, ETC.

[3] INLET MUST BE BELOW BOUNDARY LAYER

FOUR SINGLE PODS, WING MOUNTED
AXI-SYMMETRIC INLETS
INTEGRATED WING/TAIL PLANFORM

Figure 4–15. Engine Pod Location Trades

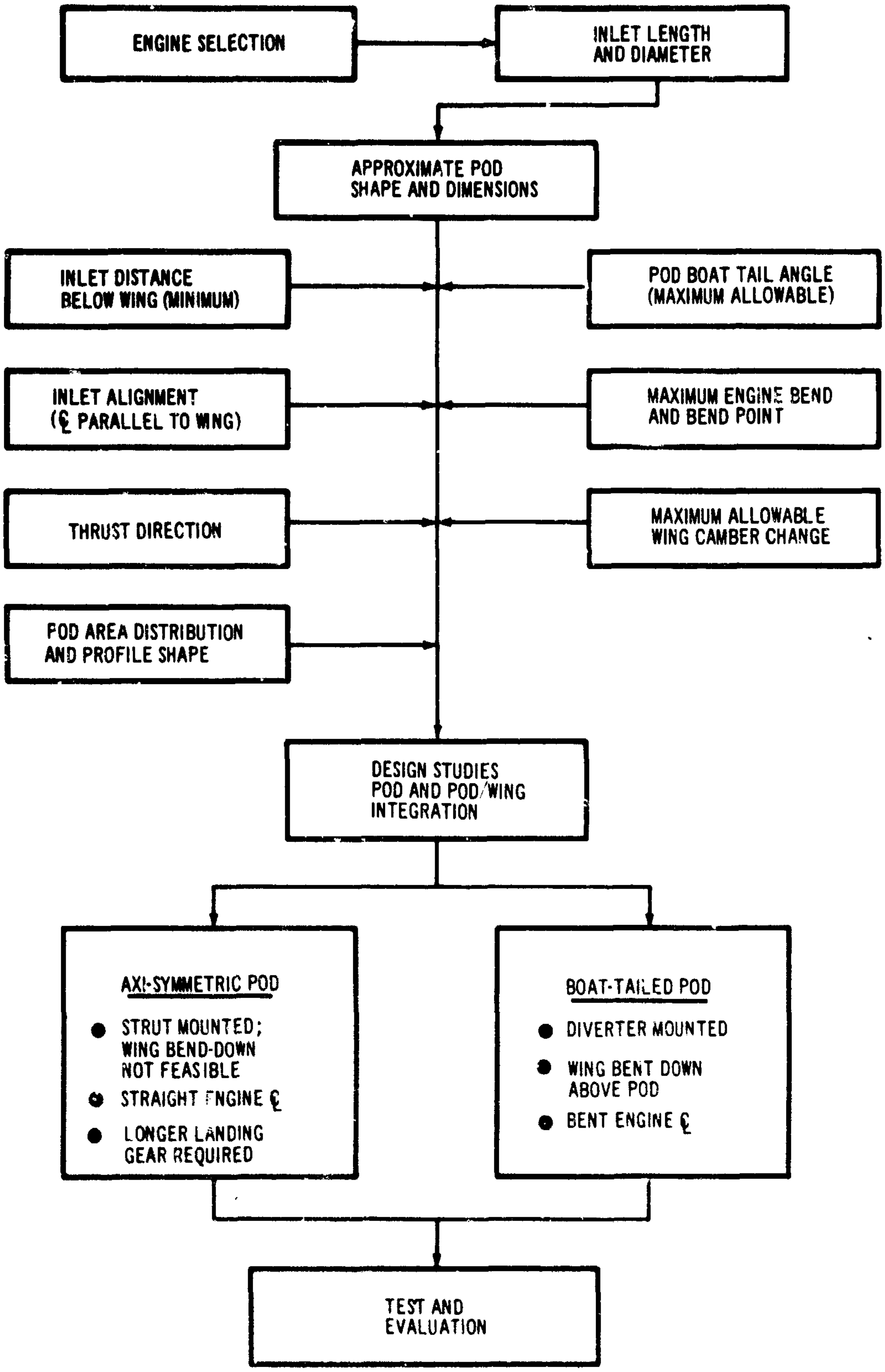


Figure 4-16. Design Sequence-Pod and Pod/Wing Integration

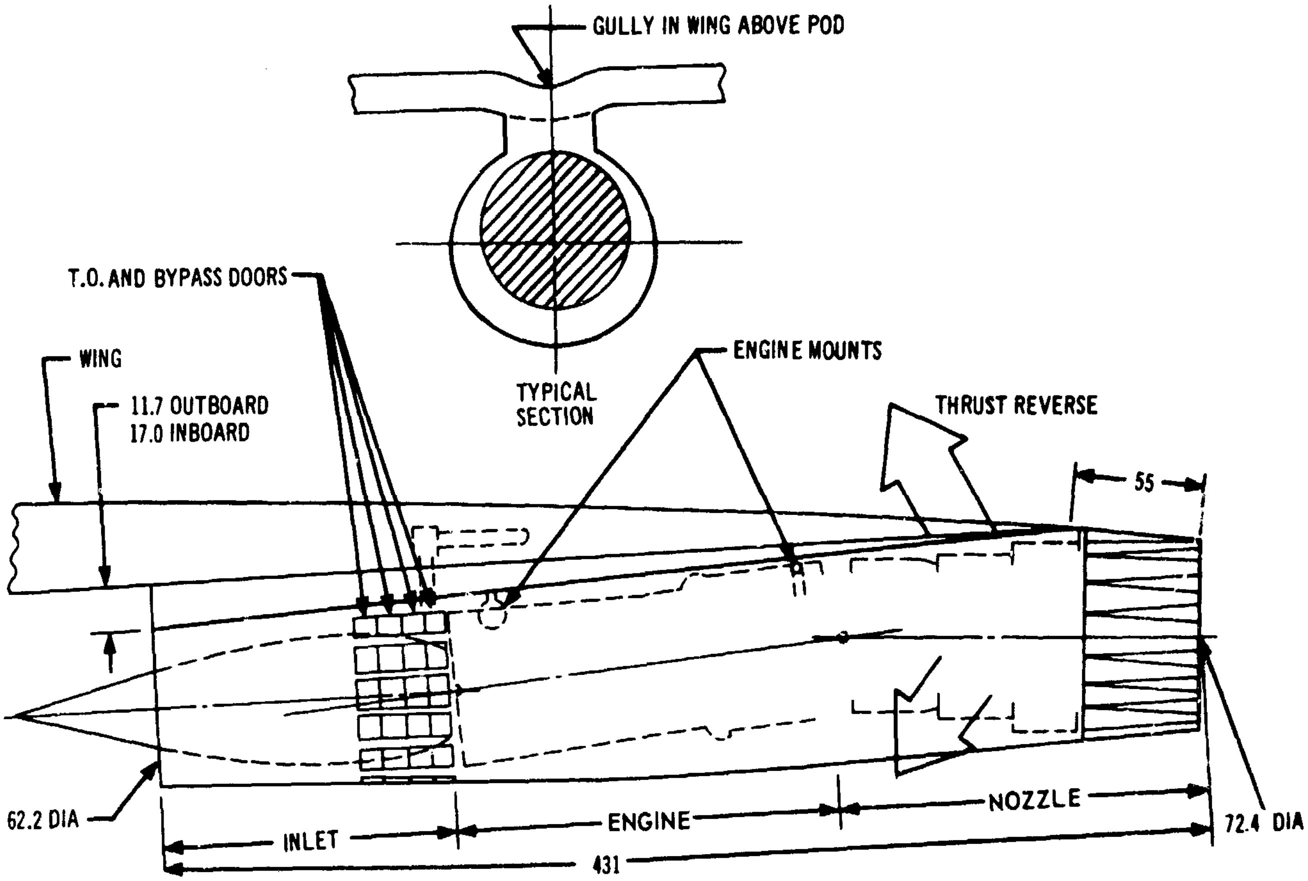


Figure 4-17. GE Pod

Airflow characteristics at the pod inlet must be virtually constant at all expected cruise flight attitudes and conditions to permit inlet design for maximum efficiency and to minimize unstart problems. Flow field studies such as Fig. 4-24 show that little variation in flow direction occurs across below-wing inlets. Fig. 4-25 indicates that a location directly above the fuselage is the best choice for minimum flow distortion when pods are mounted on the aft body. The effects of airplane attitude on inlet flow direction and resulting performance degradation are shown in Fig. 4-26. Fig. 4-27 is a typical wind tunnel test setup for flow field investigations.

Axi-symmetric inlets were selected for the B-2707 pods because they are more efficient and lighter than other types. Light weight results from their short overall length and inherent suitability as pressure vessels due to circular cross sections. Round cross sections result in minimum circumference (low drag), and facilitate integration with the engine. Axi-symmetric inlets can be employed on dual engine pods, but some of these advantages are sacrificed.

Dual engine pods were considered at various stages in the Boeing SST development program. Their principal advantages compared to single pods are:

a. Separation of pod inlets and main landing gear is facilitated, minimizing foreign object ingestion.

b. More freedom in locating flaps and/or control surface is possible because the wing trailing edge is interrupted at only one place.

c. Exhaust plume more localized. This is of interest for arrow wing airplanes with engines mounted forward.

Analyses have shown that dual pods have the following important disadvantages, however:

a. Appreciably greater weight.

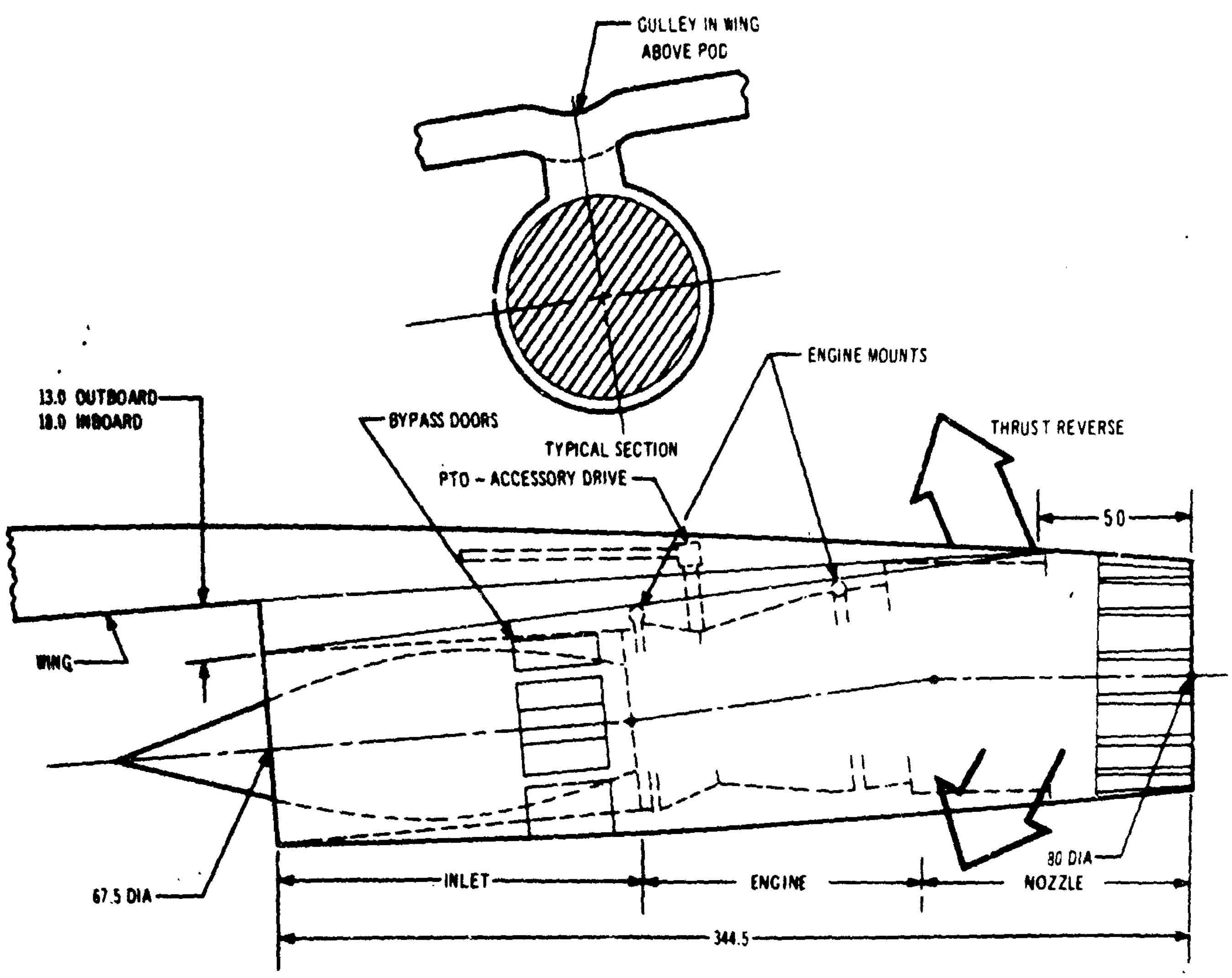


Figure 4-18. P&WA Pod

b. Higher inlet spillage and base drag.

c. Greater fire and compressor/turbine disc fragment hazard due to close proximity of engines.

Designs for dual pods using several types of axisymmetric and two-dimensional inlets were prepared and evaluated (Fig. 4-28). In all cases, the disadvantages of the dual pod (safety, weight and drag) were judged too severe for their use in a commercial supersonic transport.

The B-2707 inlets and pod installations are designed to minimize the possibility of inlet unstart occurrence under any conditions encountered during normal flight. Unstart is a disturbance in which the normal shock at the inlet throat is expelled, Fig. 4-29. Pressure recovery - and hence engine thrust - drop almost instantaneously. Although B-2707 inlet unstart is highly unlikely, the possibility exists due to severe environmental distrubance. For this reason, each inlet system includes automatic restart capability. The inlet is restarted in one second, and full performance is restored in two seconds.

Methods for preventing induced unstart from adjacent failed pods were developed in a program of studies and wind tunnel investigations. The simplest method was found to be large spanwise spacing between pods, Fig. 4-30. Where wing

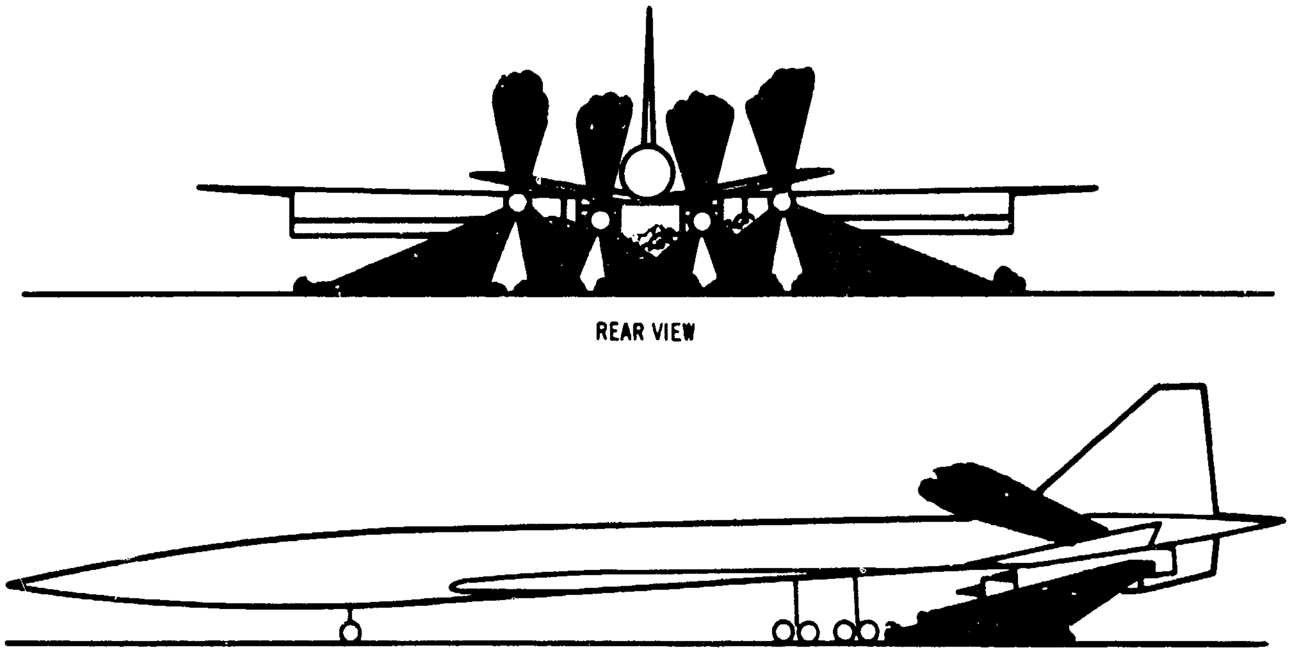


Figure 4-19. B-2707 Thrust Reverser Pattern

span is too limited to rely solely on this approach, as on the B-2707, fences can be used to provide the necessary pod isolation as shown in Fig. 4-31. Analytical effort substantiated by wind tunnel tests has determined the size and location of the fences.

4.2.2 Engine Size Selection
Selection of the engine size for the B-2707 required the achievement of the greatest range/payload capability, while meeting other critical objectives such as transonic thrust margin; airport, community and approach noise; and takeoff field length. Basic engine sizing studies were completed prior to 1 June 1966, at which time the contractors were scheduled to notify the engine manufacturers of their size requirements. Recognizing that the final gross weight selection would be somewhere between 600,000 and 700,000 lbs, the sizing studies considered this weight range. The final gross weight choice of 675,000 lbs has proven to match very well the GE and P&WA engine sizes selected.

Range

Attaining maximum range with a given airplane is of paramount importance in sizing the engine. Referring to Fig. 4-32 the GE4/J5P at 620 lb/sec sea level static airflow and the P&WA JTF17A-21 at 687 lb/sec provide maximum range for the B-2707.

Transonic Thrust Margin

One of the critical design objectives for the airplane/engine is transonic thrust margin. The objective for the airplane is a minimum thrust-margin (T-D)/D of 0.3 on a standard day climb with a sonic boom over-pressure of 2.5 psf. From Fig. 4-32, the thrust margin for the GE engine is 0.31 and 0.23 for the P&WA engine. Transonic thrust margin is the most sensitive parameter in engine sizing since small changes in engine size can have a large effect on thrust margin.

Takeoff Distance

Takeoff distance trades are shown on Fig. 4-32. At maximum augmentation, the takeoff field lengths on a +15°C day are 8,000 feet for the GE4/J5P and 8,500 feet for the P&WA JTF17A-21. The takeoff field length objective of 10,500 feet is easily met by both engines.

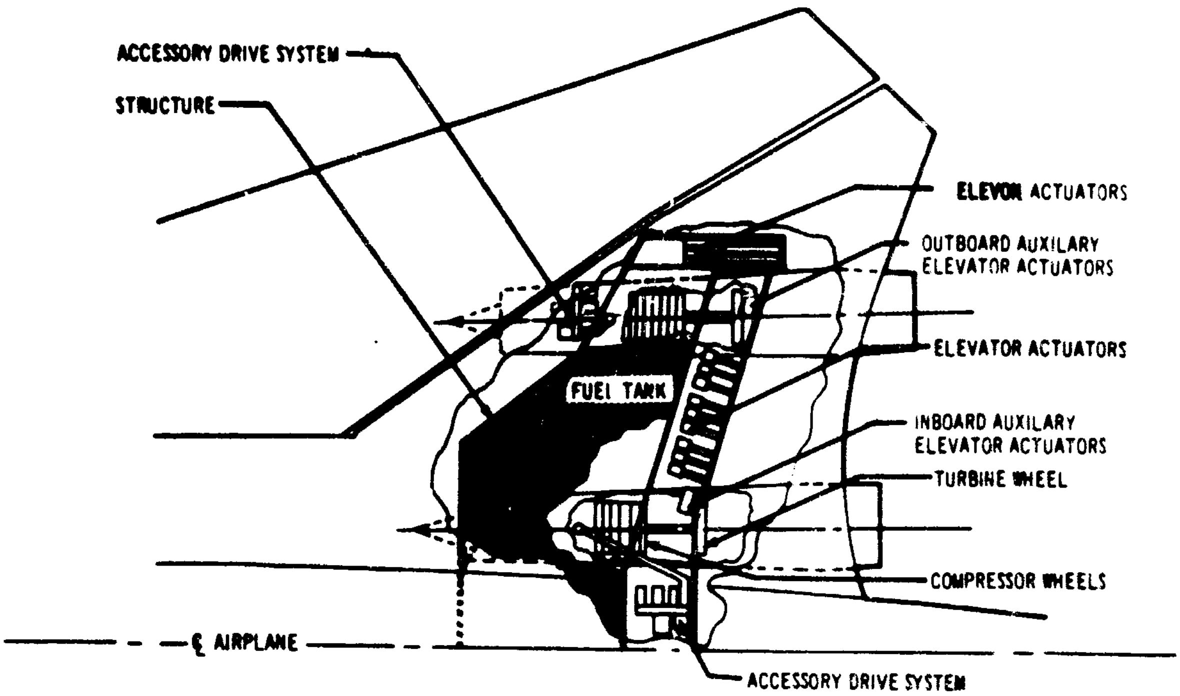


Figure 4-20 Pod/Horizontal Tail Arrangement (GE)

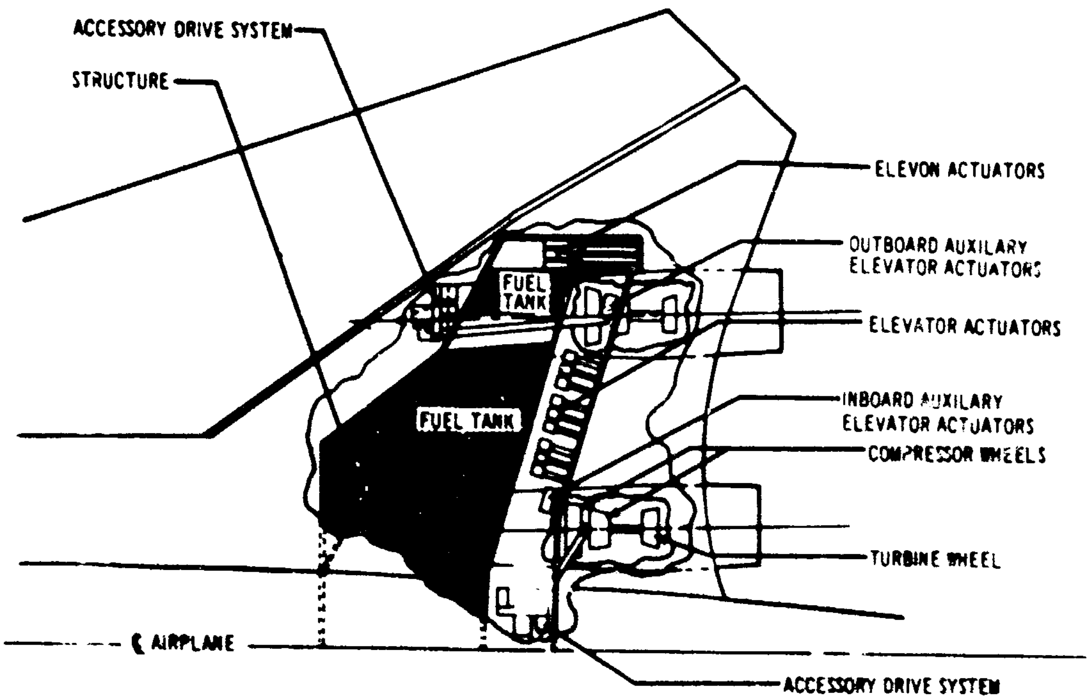


Figure 4-21. Pod/Horizontal Tail Arrangement (P&WA)

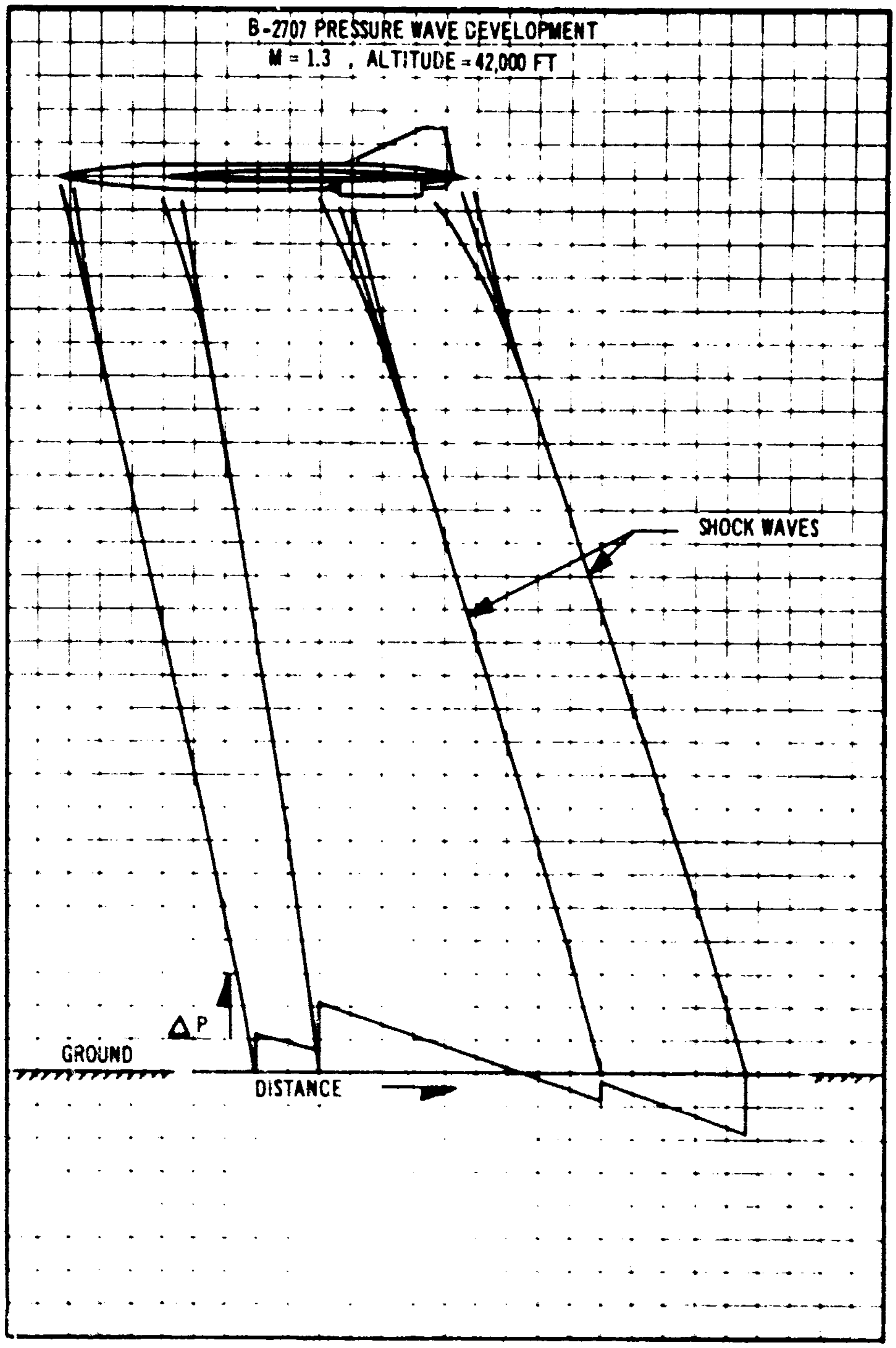


Figure 4-22. B-2707 Pressure Wave Development

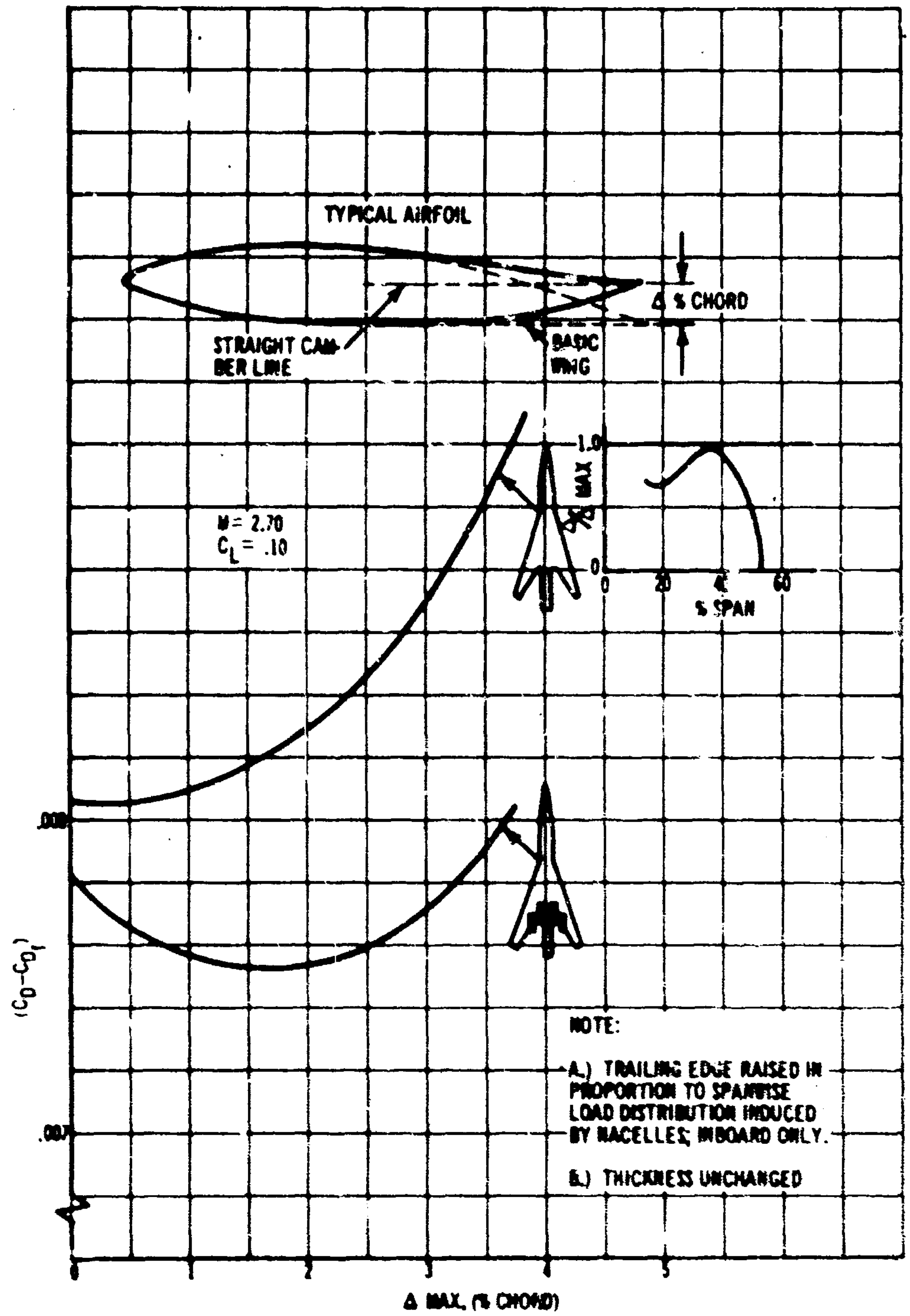


Figure 4-23. Effect of Trailing Edge Reflex on Cruise Drag

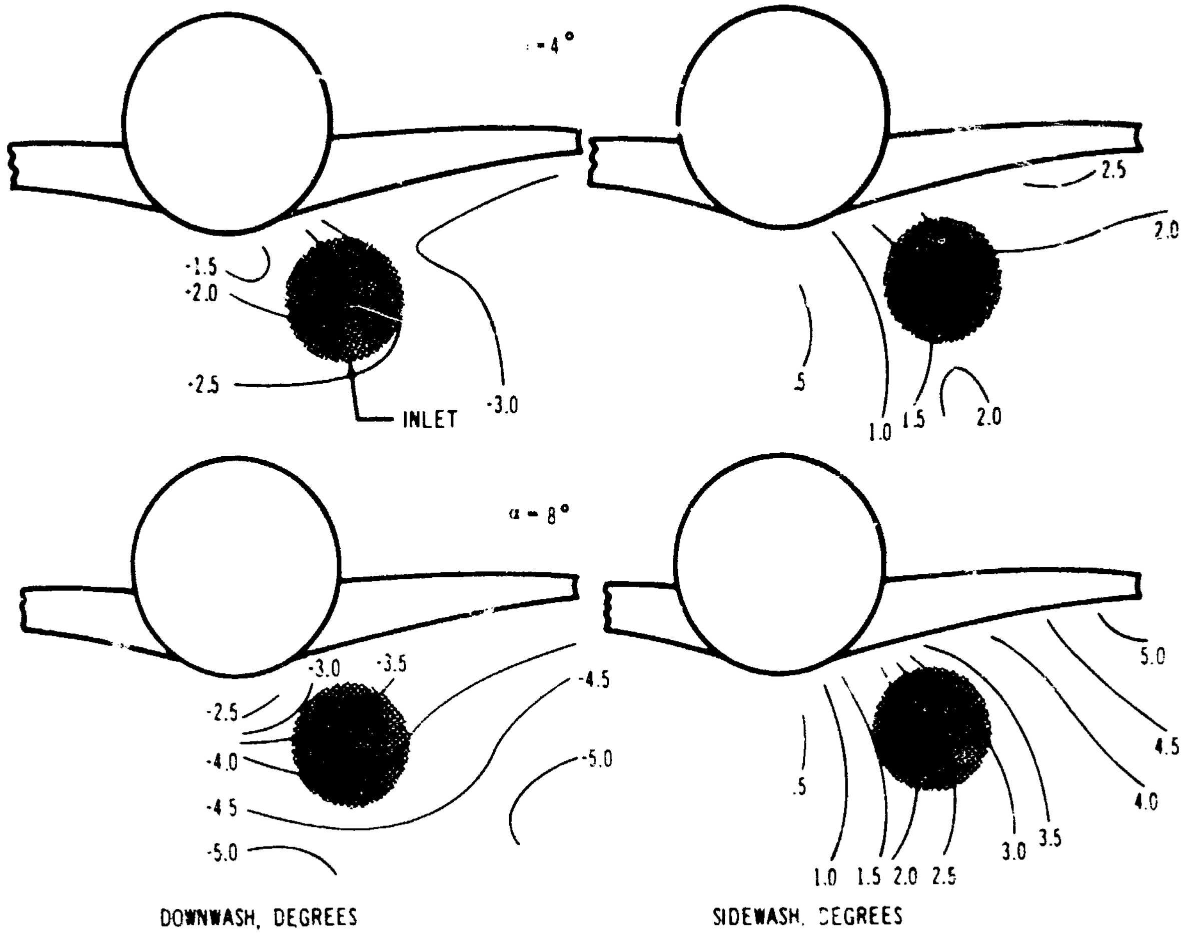


Figure 4–24. Inlet Flow Field Below Wing

Airport Noise

Airport noise is essentially independent of engine size. Airport noise values are shown on Fig. 4-33 for both engines operating at maximum augmentation. The airport noise for the GE engine is 121 PNdb, and 117 for the P&WA engine. The FAA objective is 116 PNdb.

Community Noise

Engine size has a more pronounced effect on community noise because the airplane altitude at the 3-mile point is a direct function of engine size. The noise levels are 98 for the GE engine and 105 for the P&WA engine at their selected sizes (Fig. 4-33). These values satisfy the 3-mile point objective of 105 PNdb.

Approach Noise

Approach noise for the B-2707 is shown on Fig. 4-33 and is relatively insensitive to engine size. The approach noise levels are 110 for the GE engine and 115 for the P&WA engine. The FAA objective for approach is 109 PNdb.

4.2.3 Engine Inlet Ingestion Prevention
Supersonic transport designs are particularly susceptible to inlet ingestion because the propulsion pods are aft of the landing gear. To prevent ingestion, some barrier must be provided between the wheels and the inlets. This may be done in any of the three zones shown in Fig. 4-34 - at the inlet, at the wheels, or in the intervening space. The size of the barrier must be greater if it is placed in the intervening space

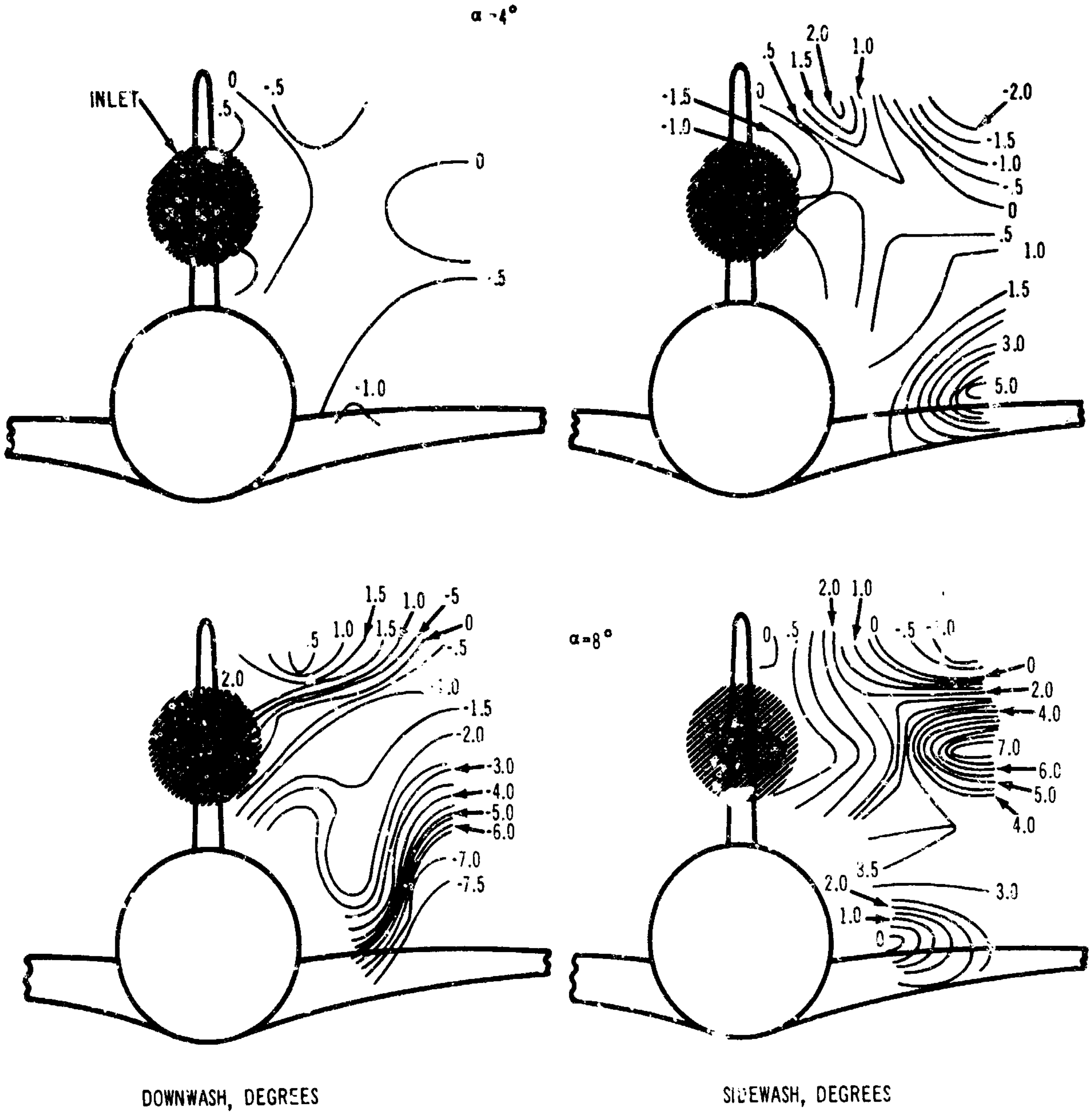


Figure 4–25. Inlet Flow Field–Tail Mounted Pods

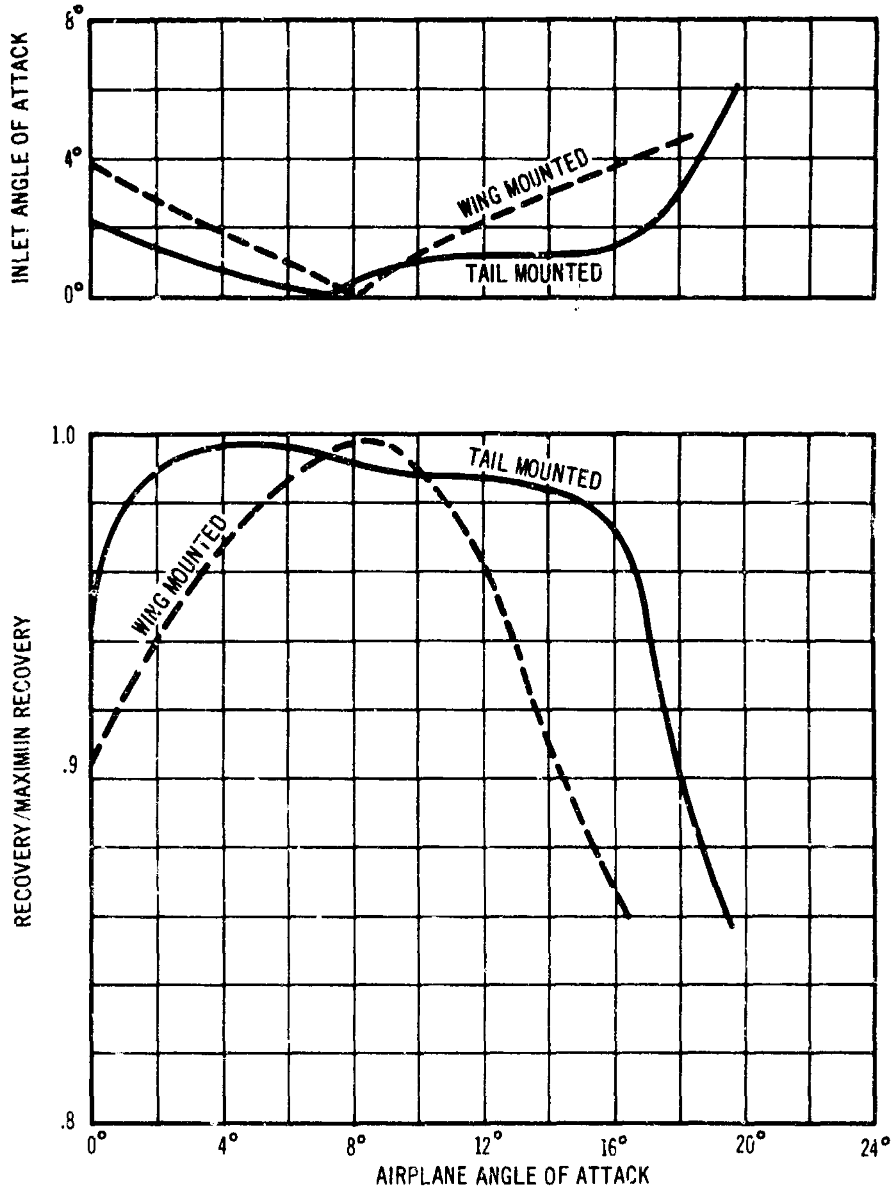


Figure 4-26. Inlet Performance

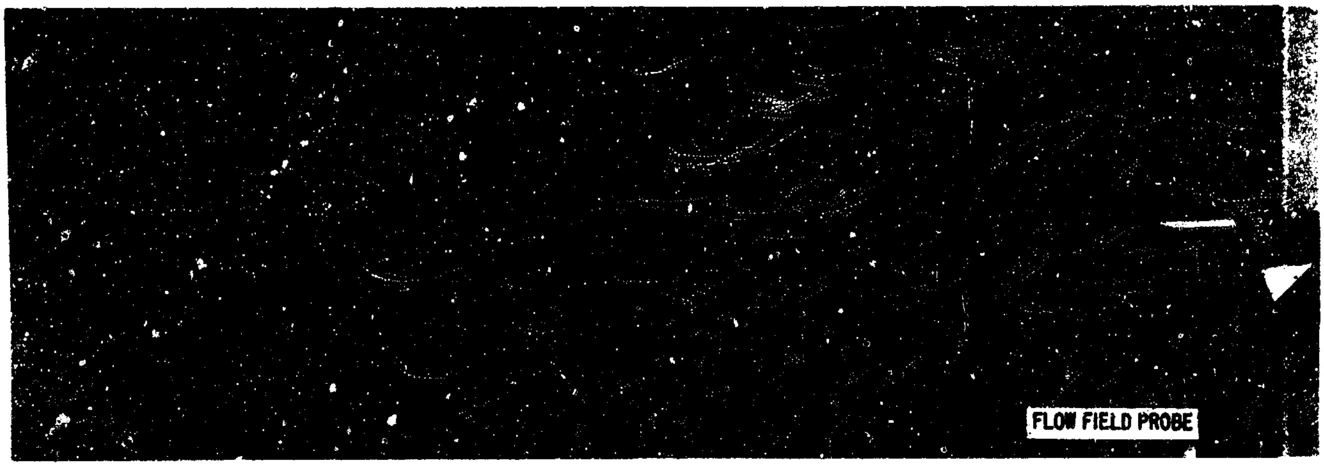


Figure 4-27. Inlet Flow Field Test Setup (Wind Tunnel Model)

rather than at the inlets or the wheels. Fig. 4-35 shows three methods for barriers at the inlets.

none of these ideas was found acceptable for one or more of the following reasons:

a. Excessive weight increase requirements - the duplicate set of bypass doors represents by itself a severe weight penalty without accounting for the weight of the foreign material barrier.

b. Airflow distortion

c. Difficulty in retracting screens without dumping the foreign material they have caught into the engines.

d. Excessive complication and resultant unreliability of mechanisms in inlet zone.

Another approach is the employment of fenders around the gear wheels (See Fig. 4-36). An extensive series of tests determined the characteristics of wheel spray. Spray deflectors (fenders) were devised which prevented the motion of spray from the wheels to the inlets. Fig. 4-37 shows an example of wheel spray. Fig. 4-38 shows effective spray suppression by an experimental deflector model. Fig. 4-36 shows that same experimental deflector in some detail.

The deflector design was also tested for its capabilities in slush. It was entirely effective in keeping slush down at runway level, just as it did the water.

Another series of tests were run to observe the performance of the wheel cover when rocks of various sizes are encountered on the runway. It showed complete effectiveness in preventing vertical motion of the rocks above the wheel level.

Practical structural wheel covers of the type shown in Fig. 4-36 will add about 1,000 lbs to the landing gear weight.

Fig. 4-39 illustrates the manner in which fully extended flaps of the B-2707 protect the inlets from water or slush spray. A model of the airplane landing gear, flaps, and inlets was constructed and photographs made from wheel positions to show what line-of-sight-paths between wheels and inlets were covered.

Thickness of the titanium skin on the lower surface of the aft flap will be three times normal honeycomb skin thickness to preclude structural damage from rocks or other foreign objects.

The selection of the flaps as protection for the inlets has other benefits. Most bird ingestion occurs in airplane motion on or near the ground; hence, the flaps will reduce bird engine damage due to ingestion. The use of the flaps also precludes ingestion of material drooping from the landing gear during its retraction. Inlet distortion due to landing gears in front of inlets is also eliminated through the use of flaps.

4.3 FUSELAGE DESIGN

Selection of the fuselage design for the B-2707 has been aimed at producing the highest perfor-

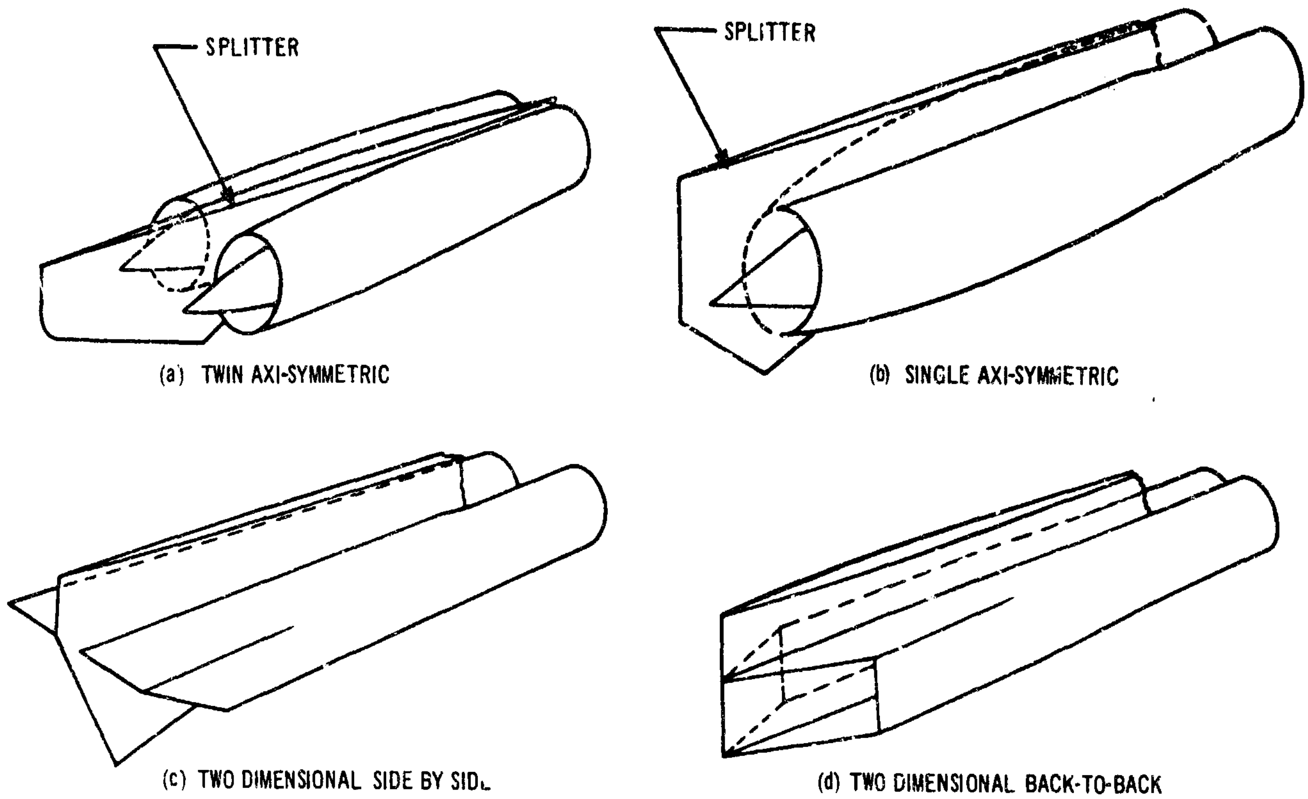


Figure 4-28. Dual Pods

mance fuselage achievable with due regard for all of the performance aspects of the airplane. The design chosen (Fig. 4-40) is an effective compromise of the basically incompatible factors of aerodynamic performance and capacity for passengers and cargo. Fig. 4-41 shows the deck plan, arranged for 277 passengers (international mixed).

The parameters affecting body development are these:

- Seating - number of seats, their sizes, clearances, number abreast, and the split of passenger classes.
- Clearances - the human engineering concern for space between passengers' heads, shoulders, arms, and hips and the interior ceiling, sidewalls, and arm rests, in both sitting and walking spaces.
- Passenger Services - galleys, toilets, personal articles stowage, etc.
- Evacuation Provisions - for safety in emergency situations.
- Baggage - capacity as well as ease of loading and unloading.
- Landing Gear Stowage - to aid in design of the safest and most reliable landing gear.
- Drag - a function of cross section, size and "area rule" contouring.
- Weight - strongly influenced by slenderness ratio and cross section.
- Sonic Boom - influenced by size, shape, and weight.

The airlines strongly recommend a constant 6-abreast seating arrangement. The 6-abreast body permits cabin arrangement flexibility to suit the airline operational requirements. The superior arrangement flexibility of the 6-abreast over the 5-abreast body provides:

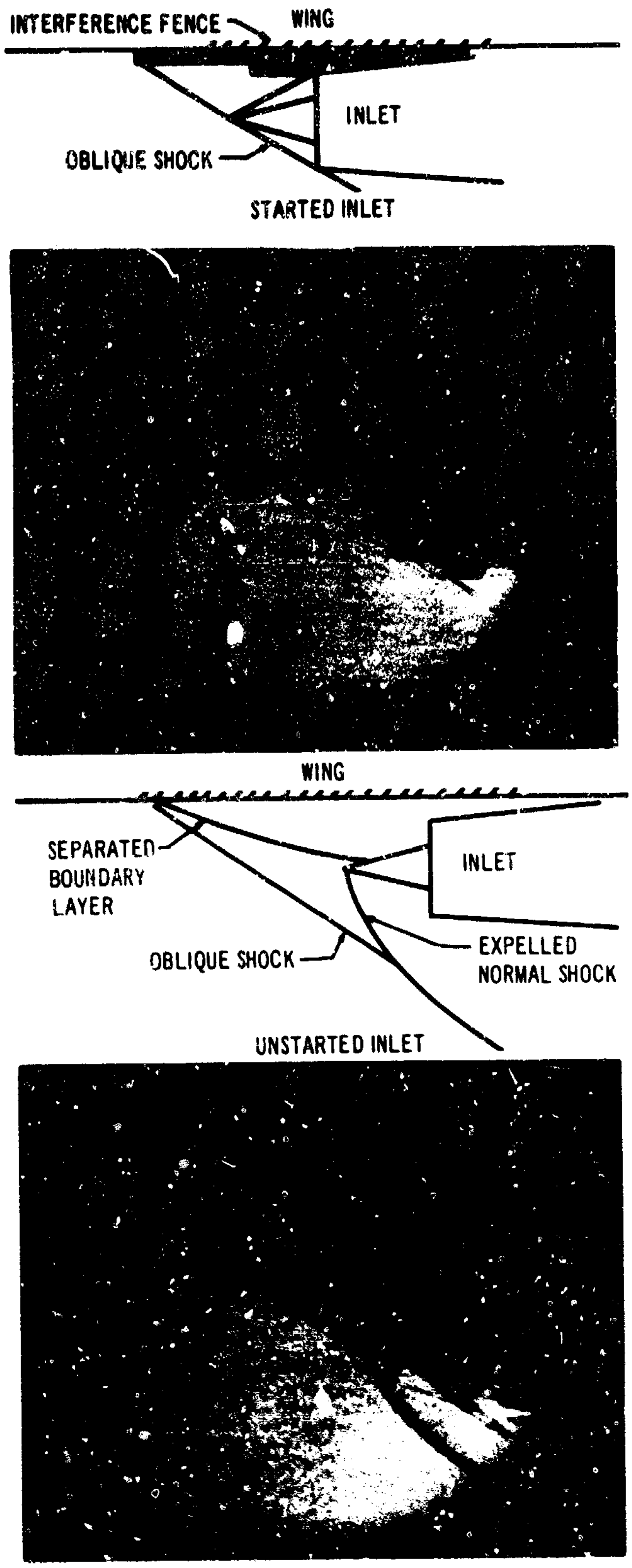


Figure 4-29. Inlet Started and Unstarted

- Symmetrical seating
- Symmetrical overhead accessories
- Symmetrical coat closets
- Galleys opposite lavatories with sufficient aisle width to prevent passenger traffic congestion.
- Balanced architecture
- Aisle centered in the area between hat racks
- More efficient utilization of the cabin air space

Careful analysis and design work was done on passenger accommodations: seats, galleys and toilets; entrance doors, emergency exits, and aisles; and baggage space. Boeing work included an anthropomorphic study of the history of human body dimensions in the past one hundred years, and a forward extrapolation of these figures to arrive at predicted passenger dimensions. A large number of body cross sections were drawn, to accommodate a 1980 "90th percentile man." These were compared with the accommodations now in use in late model jet and turboprop transports and were discussed with airline representatives. The passenger space shown in the selected body section (Fig. 4-42) was their unanimous choice.

In designing baggage and cargo space, Boeing objectives were to achieve the most in usable space, ease of loading and unloading, and maximum flexibility for either containerized or hand-loaded use, consistent with overall airplane performance. Fig. 3-9 shows in perspective the B-2707 cargo space and the manner of loading. This design will enable complete loading and unloading of containerized cargo space by four men in 23 min. This was determined by a comprehensive time and motion study.

The passenger cabin length is determined by laying out the deck plan shown in Fig. 4-41. The basic passenger cabin diameter is determined by placing inside a circle two 63-in. triple seats, 18-in. aisle, 11.0-in. structure allowance (5.5 per side) and one inch clearance on each side between the arm rest and sidewall. The vertical placement of the floor with respect to the center of the circle determines the slope of the sidewall across the passengers head and shoulders.

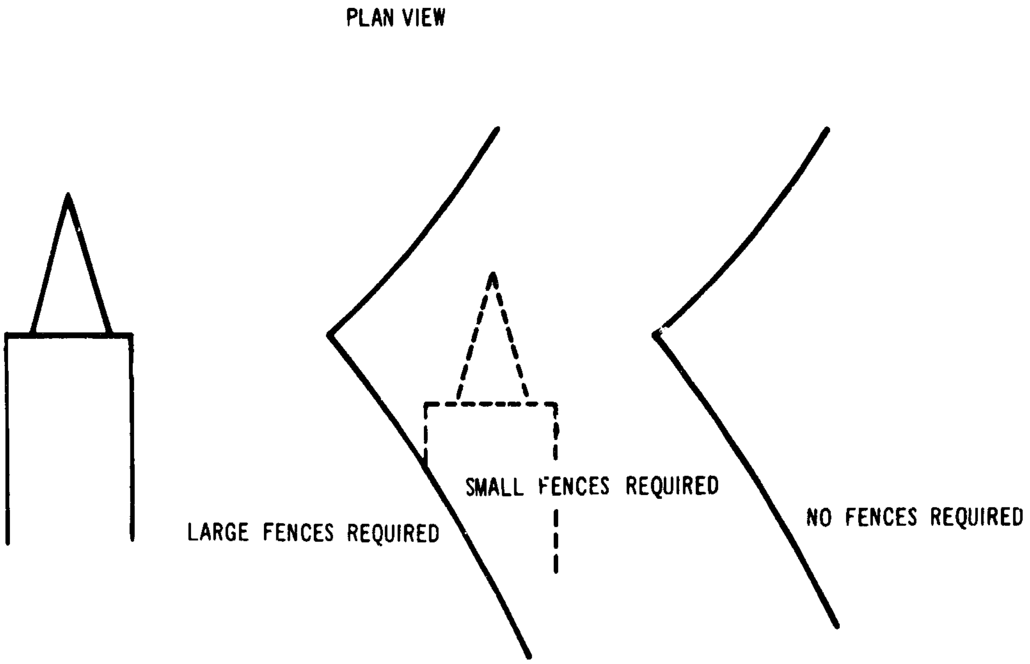


Figure 4-30. Inlet Location Restrictions

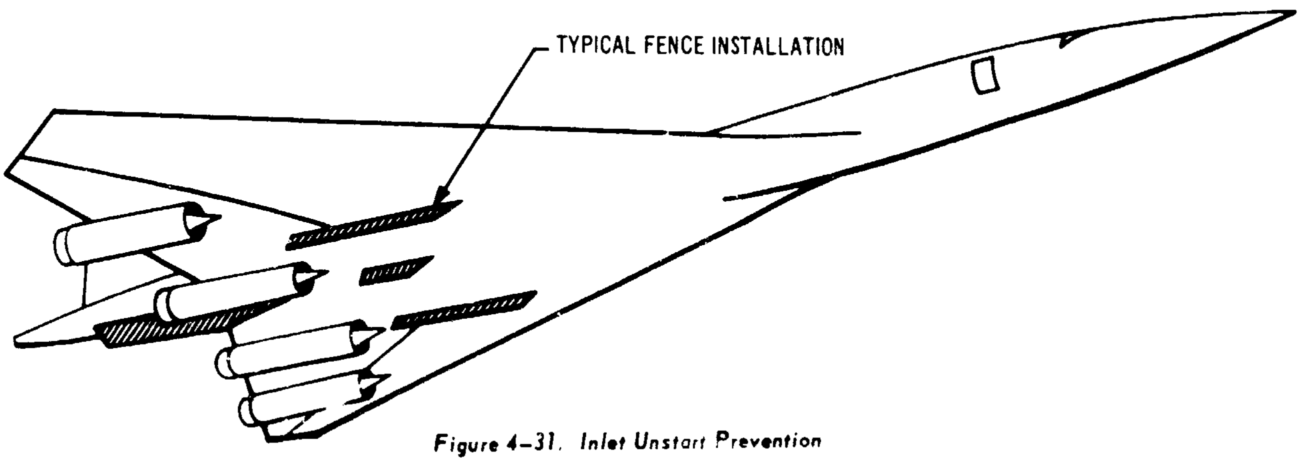


Figure 4-31. Inlet Unstart Prevention

The floor location also determines the cabin volume that must be carried in the pressurized compartment. The upper lobe of the body is circular so that the cabin pressure load can be carried in hoop tension thus providing the lightest structure.

The lower lobe of the body is influenced by the landing gear wheel well at the aft end of the cabin. The wheels and wheel clearance determine the cross section below the floor. The structural wing box between the pivots defines the body depth required at the spar stations. The 51-in. depth of the forward cargo compartment defines the lower lobe of the body at the forward end of the passenger compartment.

The establishing of the passenger cabin length, cross section, and the cargo compartment cross section permits the definition of the critical body area control points for generation of the aircraft's longitudinal area variation. The critical control points occur at the pilots station, front and rear spar of the wing, and the aft main landing gear

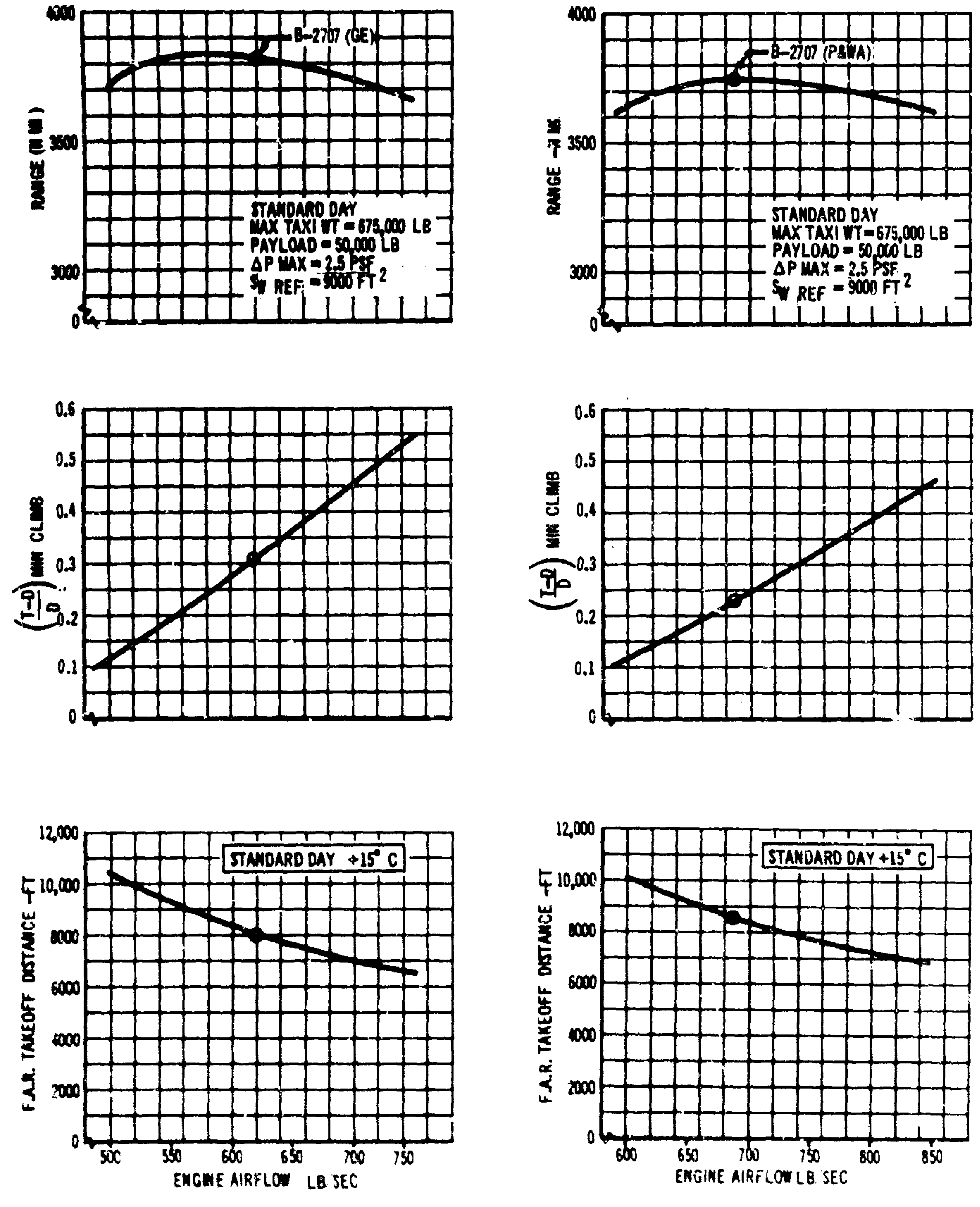


Figure 4-32. Performance Characteristics

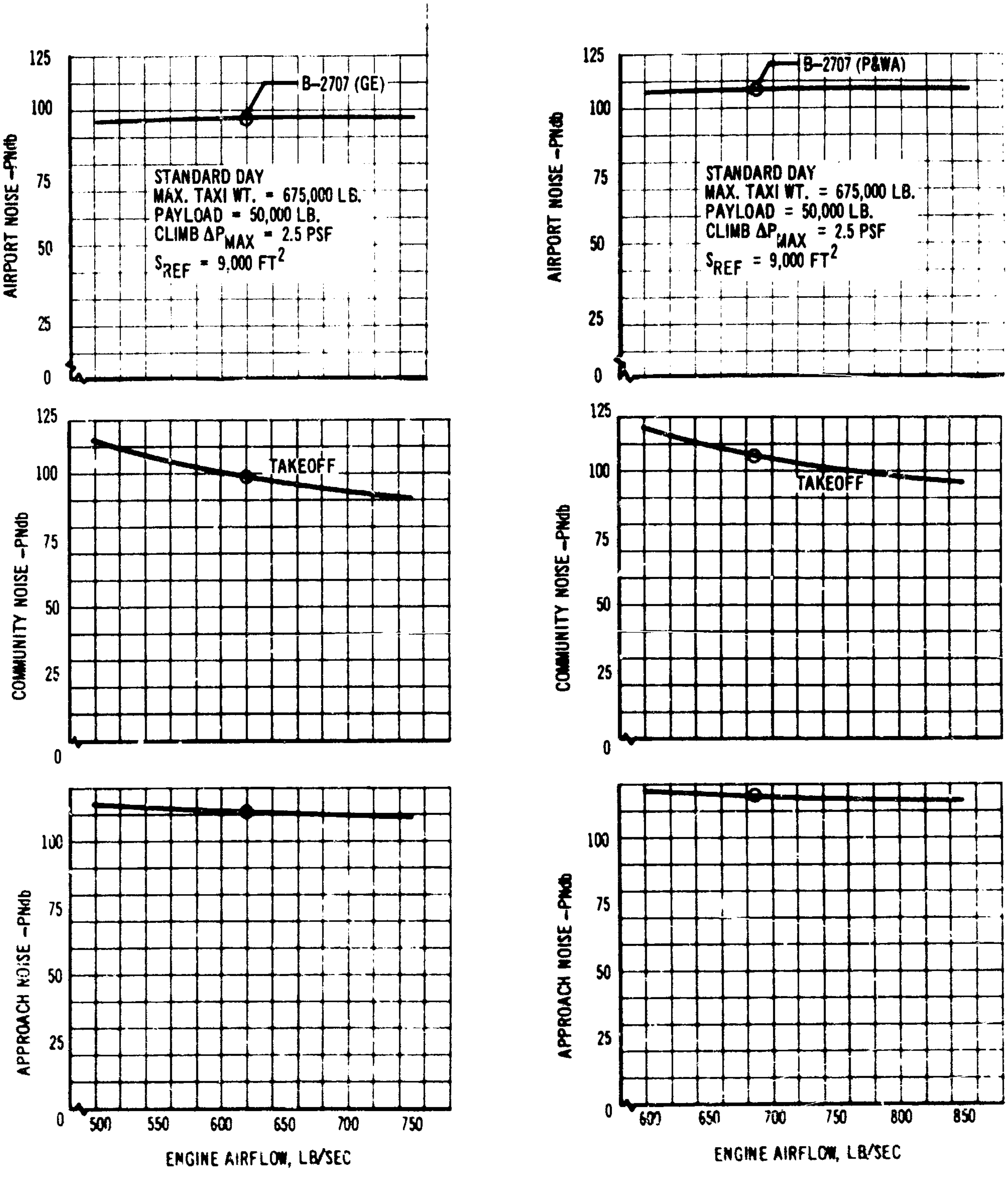


Figure 4.33. Noise Characteristics

stowage at the aft end of the passenger compartment. The length of the airplane, and the body station of each of the control points is established by preliminary layout. These locations and the body station of the wing apex are used to analytically determine the optimum area distribution.

The area variation, Fig. 4-43 was constructed by computer techniques such that the airplane wave drag is minimized. The body area distribution is then converted into body cross section elements that satisfy the passenger and cargo shape and area requirements. The body shape must satisfy not only the area distribution, but must als^ have the proper longitudinal camber and have a faired external surface, with no reverse curvature. The body camber and wing-to-body incidence are determined by the zero lift pitching moment of the airplane in the cruise attitude. The wing lower surface locates the lower body keel line forward of the wheel well. The lower forward cargo compartment establishes the lower body lines at the nose gear. The faired keel and body camber line together with the area distribution, establishes the shape and contour lines of the

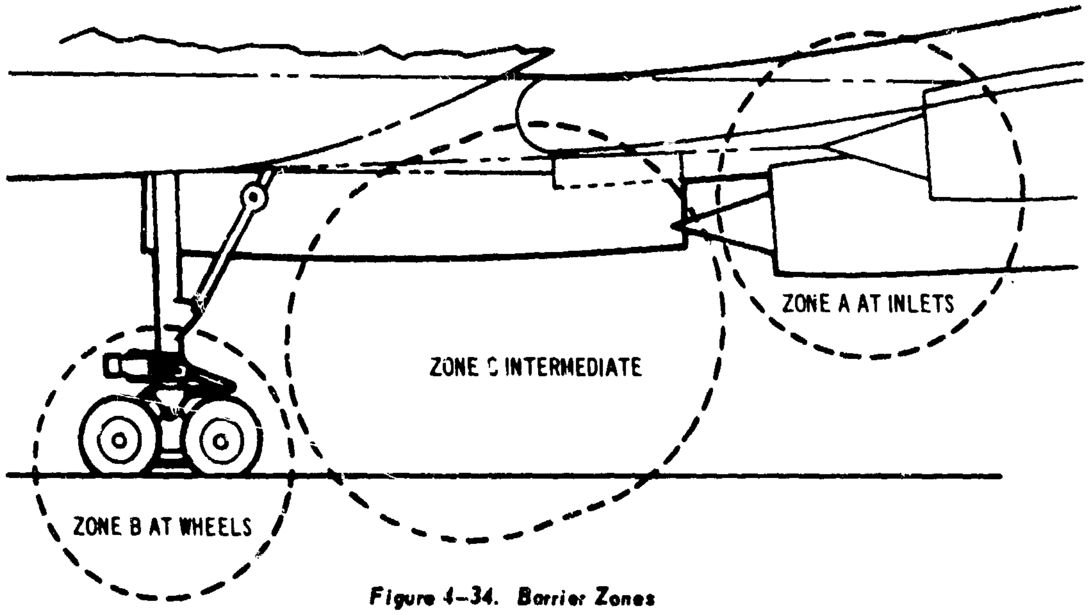


Figure 4-34. Barrier Zones

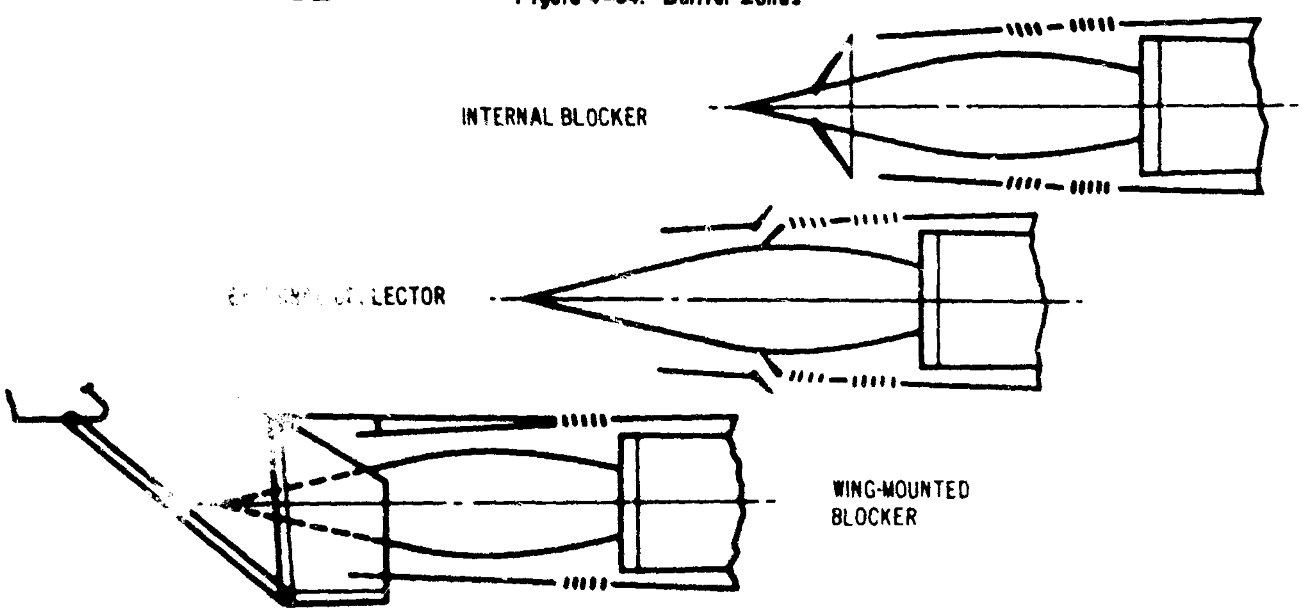


Figure 4-35. Barriers At Inlets

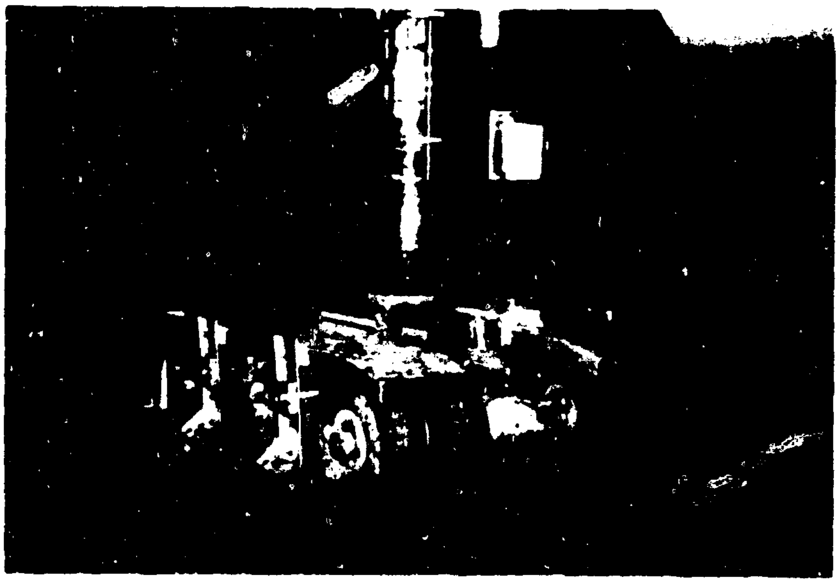


Figure 4-36. Test Wheel Cover

Figure 4-37. Spray From Wheels

Figure 4-38. Spray Supressed by Wheel Cover

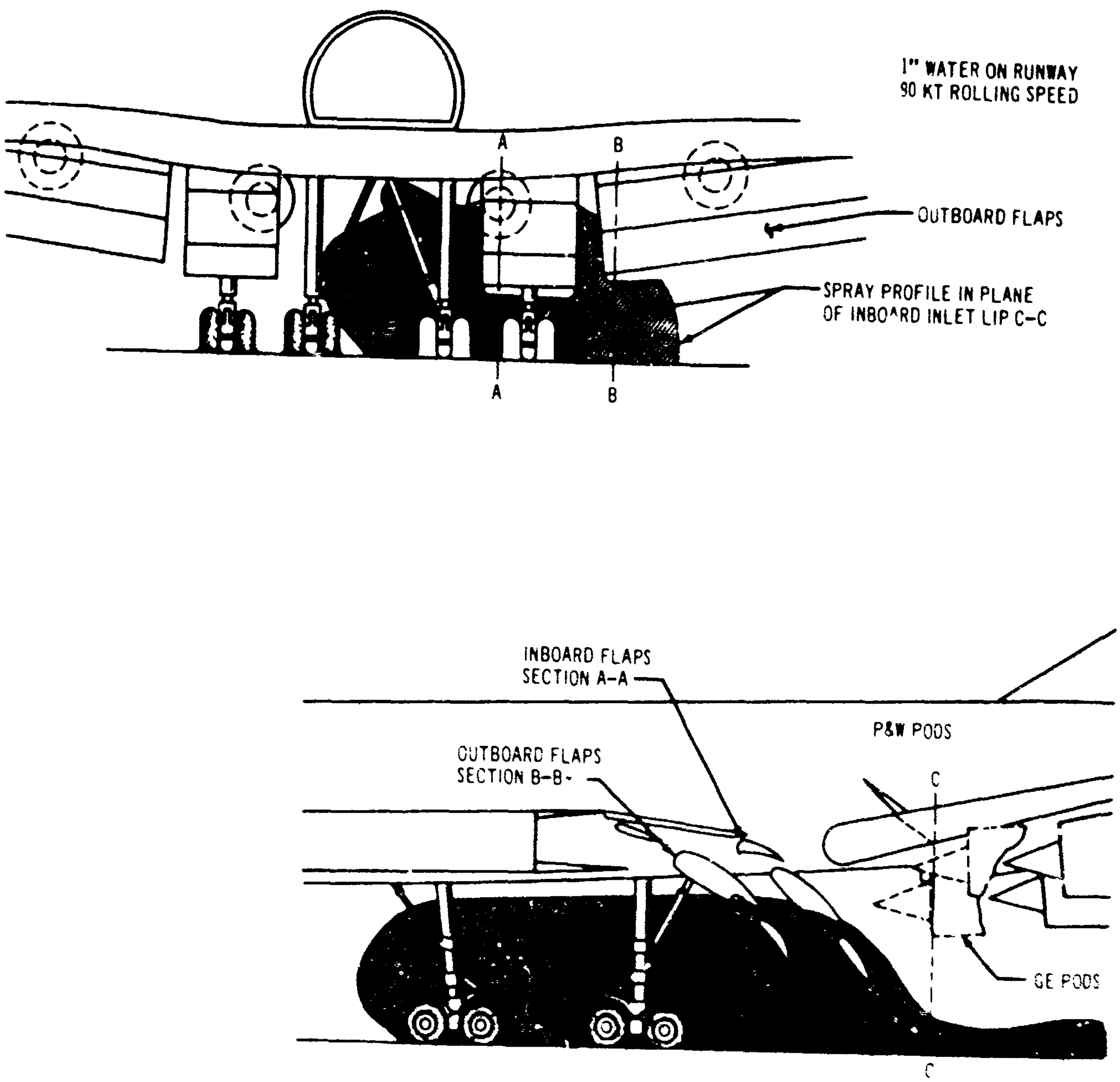


Figure 4-39. Spray Ingestion Prevention By Flaps

upper lobe of the passenger cabin. The final tailoring of the body shape is accomplished in the supersonic wind tunnel, and the iterative process recycles to obtain the proper body shape for the final configuration.

4.4 BALANCE AND CONTROL

Solution of the airplane loading, center of gravity variation, and control system requirements is the result of proper integration of many subsystem factors. The details of the B-2707 solution are discussed in several design reports noted at the end of this section. The general procedure followed and fundamental considerations assessed in the course of solving the stability and control problem are discussed briefly below.

4.4.1 Center of Gravity Limit Determination

The initial step involves determination of the aft center of gravity limit by assessment of the aerodynamic center and the desired stability margin. An assessment of the airplane in the defueled and unloaded configuration (OEW) reveals that the actual center of gravity was aft of the aerodynamic center. Therefore, a ballast tank is provided in the forward portion of the airplane to move the center of gravity forward to the aft limit for low payloads.

The forward center of gravity limit is determined by adding a full load of passengers and cargo with the wings swept forward. This is denoted the zero fuel condition and is also a condition of zero ballast.

The next step involves fueling the airplane. With the airplane fully fueled, the center of gravity falls within the aft and forward limits discussed previously.

4.4.2 Fuel Utilization

The next step involves determining the procedure for fuel utilization to assure center of gravity control within limits. Further, the program is developed to control the center of gravity to minimum trim requirement in the interest of maximizing performance. An example of fuel utilization procedures that provide center of gravity control during a typical flight profile is shown for the 50,000 lb payload case in Fig. 4-44. For further details see Airframe Design Report V2-B2707-6-1 (AL) - Part A.

4.4.3 Flight Control Requirements

(a) Pitch Control - Pitch control surface size and rate requirements are determined by the forward center of gravity limit condition during the takeoff and landing mode as shown in Fig. 4-45. Factors in addition to center of gravity that influence the surface requirements include the airplane inertia and the dead weight moment associated with the landing gear at takeoff.

Although the pitch control surface sizing and rate are determined at the low speed condition as discussed above, the maximum hinge moments are determined for the high speed maneuvering condition. Here again the forward center of gravity is the critical condition.

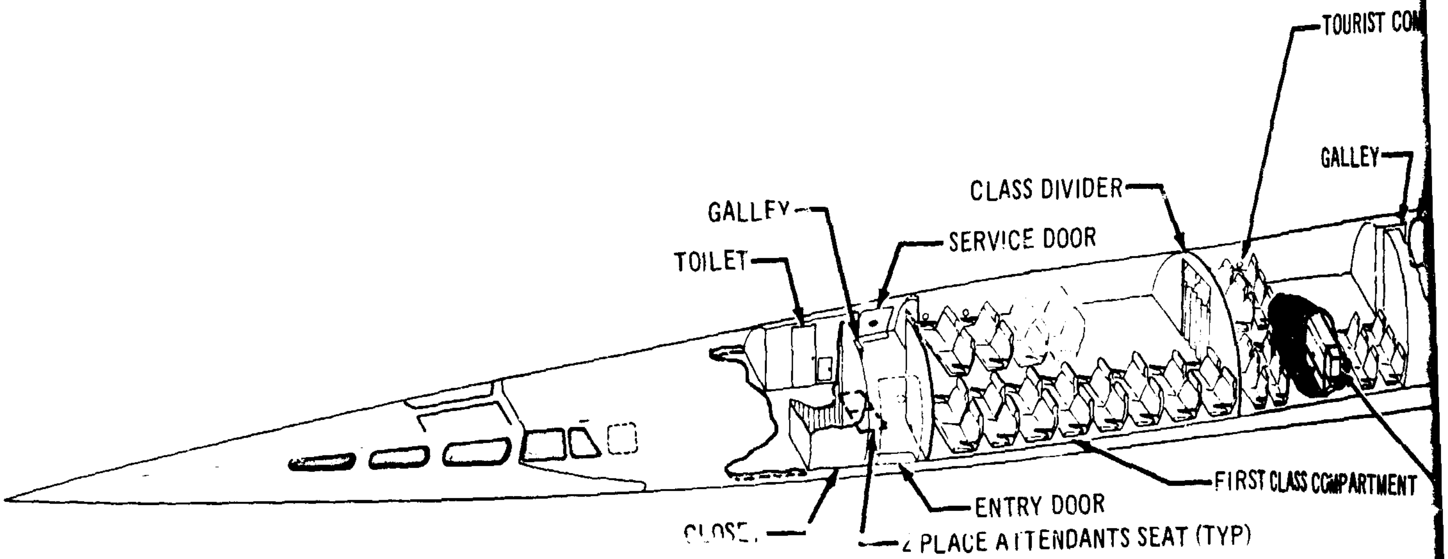
(b) Roll Control - Criteria used in establishing roll authority were based upon the objective of achieving roll performance comparable to current jet transports. These criteria are shown in Fig. 4-46 in terms of roll rate versus bank angle attainable in one second for two conditions - takeoff and landing, and cruise. As the figure indicates, the B-2707 satisfies these criteria for both conditions. These good lateral control characteristics are monitored in yawed flight during the critical low speed operation in cross wind conditions due to the ability of variable sweep wings to separate the pitch and roll control systems.

(c) Yaw Control - Rudder sizing is the result of minimum control speed requirements during takeoff with one outboard engine out. The capability of the B-2707 is shown in Fig. 4-47 for various gross weights indicating that adequate yaw control is provided with augmented thrust at high gross weight and with dry thrust at the associated lower gross weights.

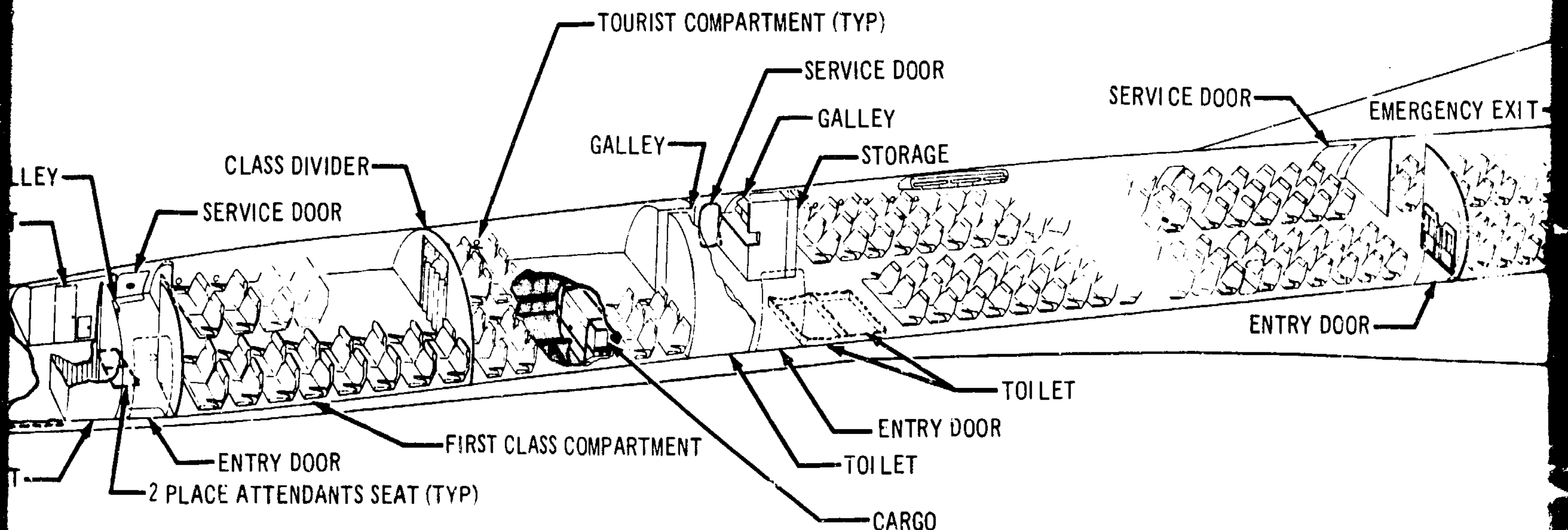
4.4.4 Reference Documentation

The above discussion reviews the considerations that led to the establishment of general requirements in the three areas of (1) weight and balance, (2) fuel system utilization, and (3) flight control. Details relative to these three areas may be found in documentation as tabulated below:

a. Weight and Balance - "Airframe Design Report - Part A" V2-B2707-6-1 (AL)



TOURIST CO
GALLEY
CLASS DIVIDER
GALLEY
SERVICE DOOR
TOILET
FIRST CLASS COMPARTMENT
ENTRY DOOR
2 PLACE ATTENDANTS SEAT (TYP)


TOURIST COMPARTMENT (TYP)
SERVICE DOOR
GALLEY
STORAGE
GALLEY
CLASS DIVIDER
LLEY
SERVICE DOOR
SERVICE DOOR
EMERGENCY EXIT
ENTRY DOOR
TOILET
ENTRY DOOR
TOILET
ENTRY DOOR
FIRST CLASS COMPARTMENT
2 PLACE ATTENDANTS SEAT (TYP)
CARGO

B

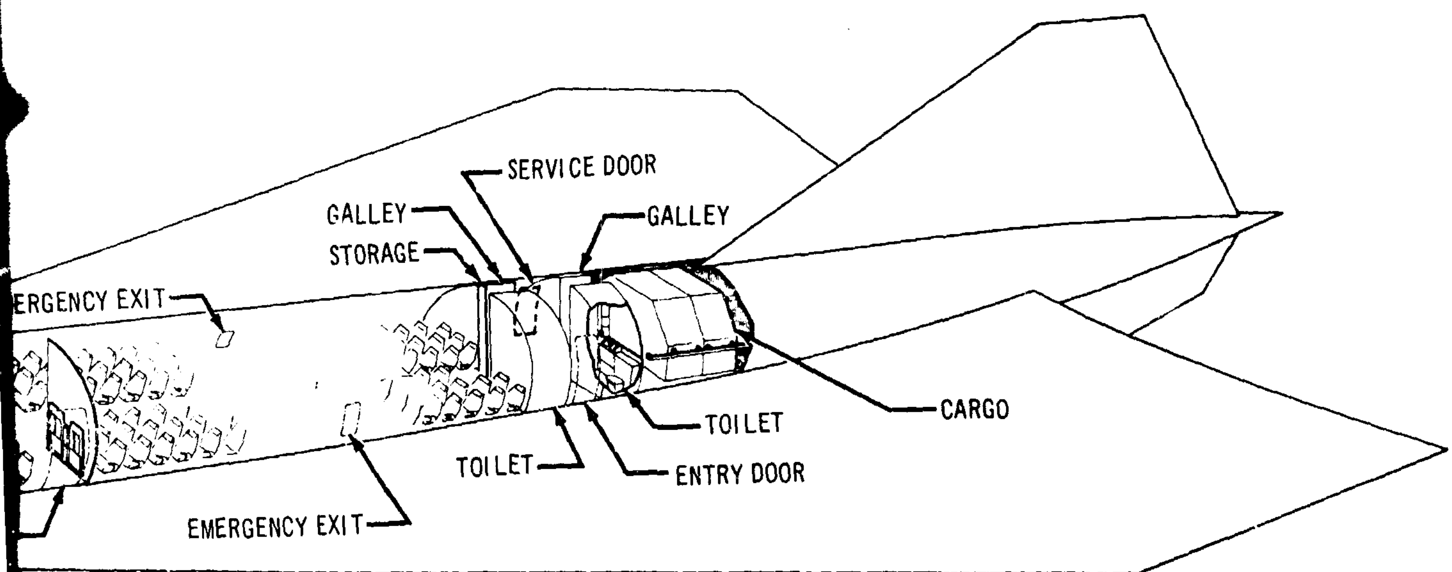


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Figure 4-40. B-2707 Body Cut Away Section

b. Fuel System Utilization - "Propulsion Report - Part B" V2-B2707-13

c. Flight Control - "Aerodynamic Design Report" V2-B2707-3

4.5 LANDING GEAR

Integration of the landing gear into the configuration involves primary considerations of flotation, gear length, and stowage.

The supersonic transport must operate from present-day airports. The Airport Operators Council in cooperation with the FAA has established as a design goal for the SST, airport pavement loading comparable with the DC 8-55 at 328,000 lbs gross weight. Because the B-2707 is approximately twice the weight, it became necessary to devise a landing gear which would apply loads no more severe than are presently being sustained by airport pavements.

Runways and taxiways are constructed of either flexible (asphalt) or rigid (concrete) pavement. Flexible pavement is more critical to landing gear design. Furthermore, flexible pavement is used extensively on both U.S. and non-U.S. airports. Therefore, flexible pavement compatibility is necessary. Flexible pavement is primarily sensitive to the load per main gear. For a fixed number of gears, flexible pavement depth requirements increase as airplane weight increases. An increase in the number of tires therefore makes essentially no difference in pavement depth. Any airplane of this weight class having only two main gears will require 30 percent more flexible pavement depth than the DC-8-55 on good grade subgrade. With a marginal subgrade this depth increase becomes as high as 50 percent.

4.5.1 Main Gear Investigation (Two-Post)

Although flexible pavement compatibility is improved by increasing tire spacing, an excessive spacing increase would be required to make the B-2707 airplane with two main gears equivalent in loading to the DC 8-55. Fig. 4-48 (two-post) shows a main gear which was studied for the B-2707 as a two-gear arrangement which meets the pavement loading requirements. The wide tread of the gear causes high torsional loads and excessive tire scrubbing. High beam deflections and uneven truck loading on crowned runways is also objectionable. The large truck envelope is not consistent with the need for minimum stowage volume.

If current airport pavement requirements are to be met as airplane weights increase, a change from the normal two-main-gear concept is required. Growth of the airplane is clearly impractical unless more than two gears are employed.

4.5.2 Main Gear Investigation (Three-Post)

Investigation was made of three-gear arrangements having four, six, and eight tires per truck. Each arrangement showed improvement over two gears with flexible pavement capability, but the desired flotation was not achieved (Fig. 4-49 Line 2). The four-tire truck was considered not acceptable because the number of tires (12) produced a high-unit tire loading and the required tire was too large for the available stowage space. The six-tire truck yeilds the optimum number of tires (18) for practical unit tire loading and tire side. However, the gear arrangement proved to be the heaviest of the three-gear arrangements, and was evaluated least compatible with the airframe stowage space. The eight-tire truck would not only impose severe stowage penalties, but because of the large total number of tires (24) is considered highly undesirable from a maintainability standpoint.

When three or more gears are used unequal gear loading is caused by crowned runways and other pavement variations. The unequal loading results in a gear weight penalty due to the need for redundant structural design and increased individual braking capacities. Pressure manifolds between shock sturts of a multiple main gear are an answer to this unequal loading; but careful study disclosed that it is not practical with three main gears.

4.5.3 Main Gear Investigation (Four-Post)

With a four-gear arrangement, the situation is greatly improved. Manifolding can be applied to the two gears on each side of the aircraft causing them to act essentially as a single gear. This is effective whether the gears are arranged in a transverse line or staggered.

The selected staggered four-main-gear design is shown in Fig. 3-21 (four-post) and described in Sec. 3.5, "Aircraft Description." It incorporates limited hydraulic manifolding between the forward and aft main gear shock struts on each side of the airplane. Thus, vertical load is equally distributed between the manifolded gears. With the manifold, main gear tire loads and resulting pavement loads are always equalized under any

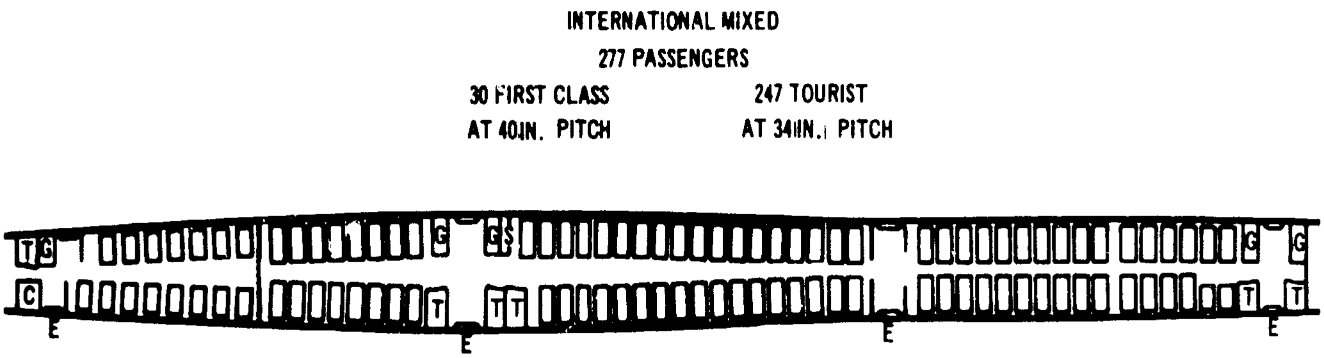


Figure 4-41. Deck Plan

condition of runway crown and uneveness. During braking no shift of load occurs between the front and rear main gears, and high braking efficiency is maintained.

The B-2707 at 675,000 lbs is equivalent in loading to the DC 8-55. The relationships of the different gear arrangements are shown in Fig. 4-49.

Landing gear length is determined by the ground clearance required for takeoff and landing. An analog simulation of the airplane has been run representing the three longitudinal degrees of aerodynamic forces and moments including ground effect, as well as the forces and moments due to oleo characteristics, thrust, and gravity. A simplified takeoff and landing autopilot was devised to provide repeatable and realistic time histories. A typical oscillograph record of a takeoff using a manifolded four-post gear is shown in Fig. 4-50.

The simulation showed that the airplane does not simply rotate about the aft gear during takeoff, but rather, rotates and lifts off simultaneously. An examination of the trace of the clearance of the ventral fin shows that the minimum clearance exists when the aft gear oleo is fully extended. It should also be noted that at the instant the gear leaves the ground the center of gravity has a vertical velocity of about two ft per sec, some of which has been furnished by the potential energy stored in the oleos. The vertical kinetic energy of the airplane allows the airplane to leave the ground at a slightly smaller angle of attack than a static solution would indicate.

The ventral clearance required for landing is a function of sink rate and oleo damping characteristics. If a long stroke oleo is used for the aft gears, landing impact energy can be absorbed in the early part of the oleo stroke, as shown in Fig. 4-51. Wing lift at landing attitude prevents large static loads on the gear so that after the impact energy has been dissipated the gear length will follow the oleo static characteristics.

The static length of the gear will depend on the stroke beyond that required to absorb a maximum sink rate landing, a long stroke permitting a shorter outer cylinder and a lighter weight.

The length of the outer cylinder of the aft gear will also be influenced by manifolding requirements. The simulation indicates that the manifold is effective in reducing elevator control requirements for takeoff rotation. Six inches of differential motion have been allowed on the aft gear for pitch rotation freedom.

The forward main gear design is influenced by manifolding required for load equalization with the aft gear, and also airplane sway stability in turns. Runway uneveness requires ±4 in. of manifold freedom to assure equal gear loads when taxiing across the maximum crown or dip. A high compression ratio oleo has been selected for the forward main gear to provide good ground turn stability characteristics.

Dynamic analysis indicated that the static ground clearance could be reduced by 20.6 in. relative to that indicated by static analysis.

4.6 PILOT VISIBILITY

Good pilot visibility is essential to assure safety in takeoff and landing; to assist in collision avoidance in heavy traffic regions; to aid in weather and terrain avoidance; and to provide attitude, tracking, and heading references when flying VFR.

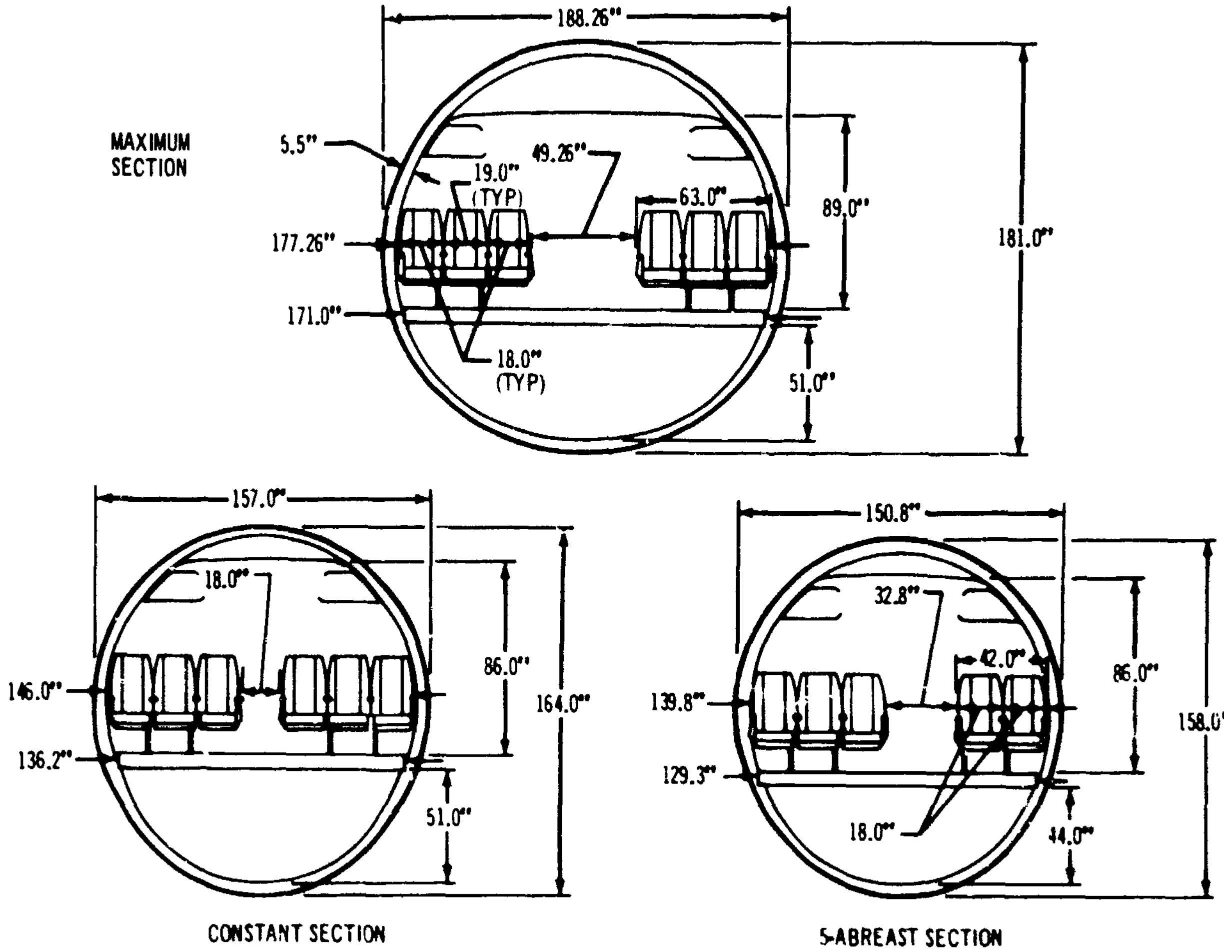


Figure 4-42. B-2707 Typical Body Cross Sections

Experience gained over the years in the development of transport aircraft has led to the establishment of various vision requirements. These are defined by FAR 25, by the Tentative Standards for Supersonic Transports, by Civil Aeronautics Manual 4b (now superseded) and by the Society of Automotive Engineers Aerospace Standard 580. The latter two are the most definitive and are shown in graphical form in Fig. 4-52.

Providing a large field of forward vision comparable to that of Fig. 4-52 for supersonic operation would penalize airplane performance severely. The supersonic arrangement must be a compromise of the drag, vision, and weight characteristics, without sacrificing safety of operation. Vision requirements have been the subject of many SAE S-7, Flight Deck and Handling Qualities Committee meetings. It is the consensus of the airline and ALPA representatives on the committee that the supersonic vision criteria which they have proposed as Revision A to SAE AS 580, and quoted in Paragraph 2.11.1 of V4-B2707-1, are realistic. In addition, dynamic simulator programs have confirmed the adequacy of the proposed Revision A to SAE AS 580 and, therefore, this has been used as the basis of the B-2707 cruise windshield design.

The most demanding low speed vision requirement is for approach, as proposed by the same revision to SAE AS 580. This requires the downward vision to provide a horizontal view of the approach lights equivalent to three secs. of approach flight when the runway visual range (RVR) is 1,200 ft and the wheels are at 100 ft altitude on a 2-1/2 degree glide slope. The requirement is illustrated by Fig. 4-53. Since the B-2707 flap system permits

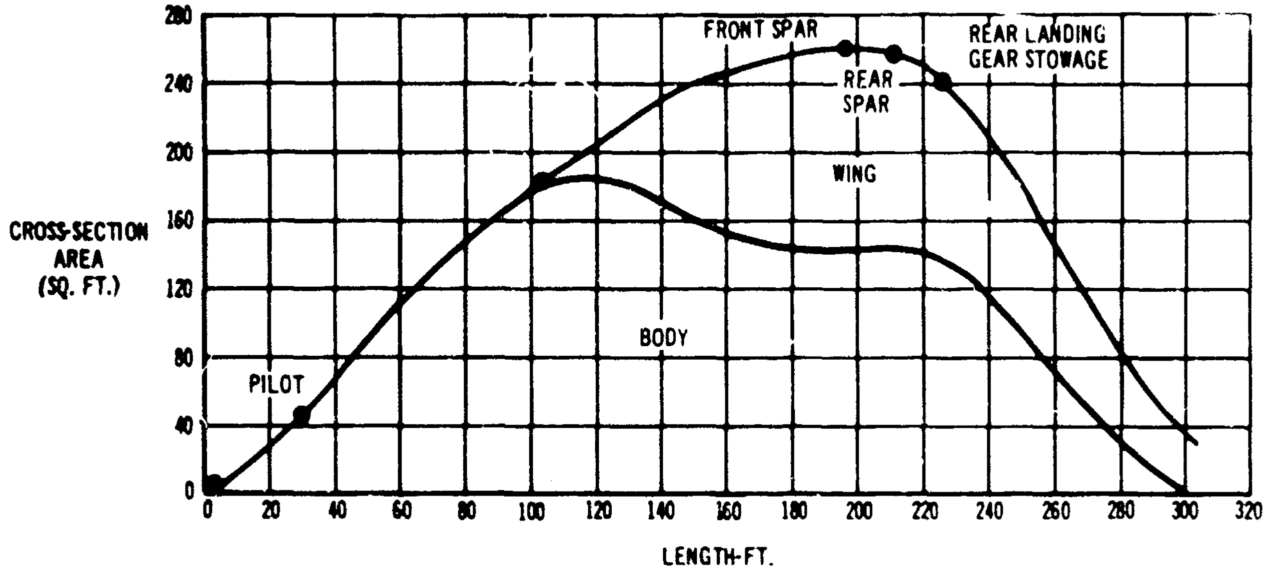


Figure 4-43. Area Variation Control Points

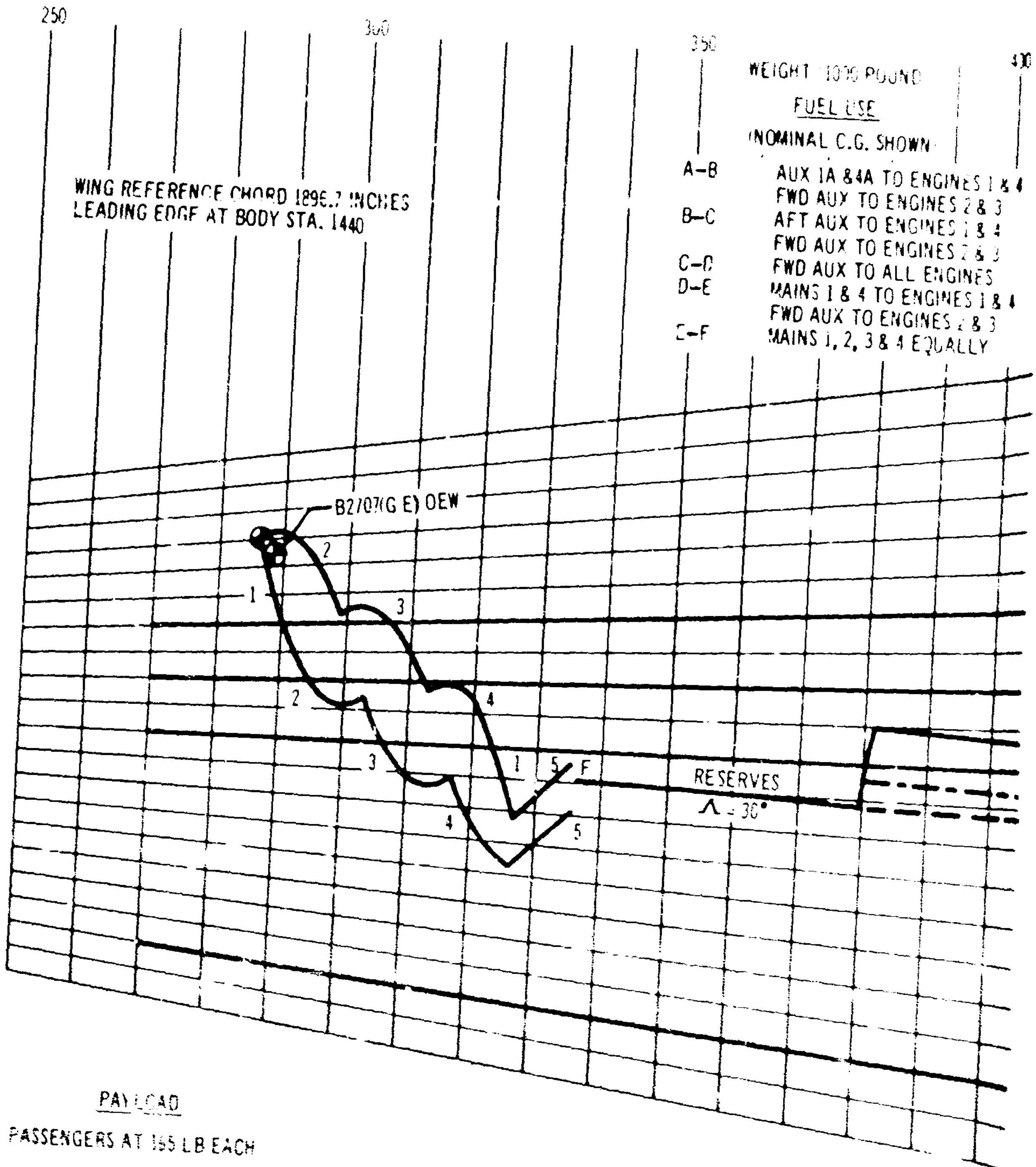
a variety of approach configuration choices, with attitude, flap setting and speed as variables, a design point was selected for vision definition purposes as shown in Fig. 4-54. The design point is based upon V ref = 135 knots and the use of full flaps. When the corresponding attitude is fed into the approach geometry of Fig. 4-53 the required down vision angle is 22-1/2 degrees.

Having defined the vision requirements the remaining constraints to the forebody design are flight deck cross-sectional area, forebody drag, and weight. The critical cross-sectional area is at the location of the pilots' eye reference station where space must be provided for the two side-by-side pilots, the aisle throttle control stand, and flight kit stowage between the seats and the sidewall. Once the cross-section is established, selection of the forebody is a compromise of the two remaining elements, drag and weight. In these studies weight effects have been converted to equivalent drag. Figure 4-55 illustrates a few of the steps involved in the evolution of the B-2707 forebody shape and mechanization.

Many approaches were considered. An early idea was the fixed nose; this did not allow attainment of adequate forward vision with an aerodynamically practical forebody design. Another concept employed a horizontally translating nose with long, high slant angle windows. This did not provide acceptable optical characteristics or practical forebody window sizes. A further approach employed a visor fairing wherein the visor was depressed into the forebody (Fig. 4-56). This required a minimum of complexity and weight but left the radome as an obstruction to the low speed vision during crosswind approaches. A third concept was considered using forebody down rotation only (Fig. 4-57). This technique, although relatively simple, left only about three ft of ground clearance at the tip of the forebody during ground operations, exposing it to contact with fences or snowbanks and to damage while on the ramp from ground handling equipment. The nose down orientations of the air data systems pitot-static head and the weather radar antenna were vastly different than orientation during cruise flight, necessitating additional complexity and the possibility of degraded sensor reliability.

The B-2707 forebody (Fig. 4-58) solves these problems while allowing 22 degrees of down vision. Relative to the seated plane of the pilot this provides 16 degrees down vision and 23 degrees of up vision, compared with 15 and 20, respectively, for a B-707. See Fig. 4-59.

The excellent visibility during approach is illustrated by Fig. 4-60 which is with the wheels at 100 ft altitude and 1,550 ft before the threshold, on a 2.5 degree glide path. Fig. 4-61 is at touch-

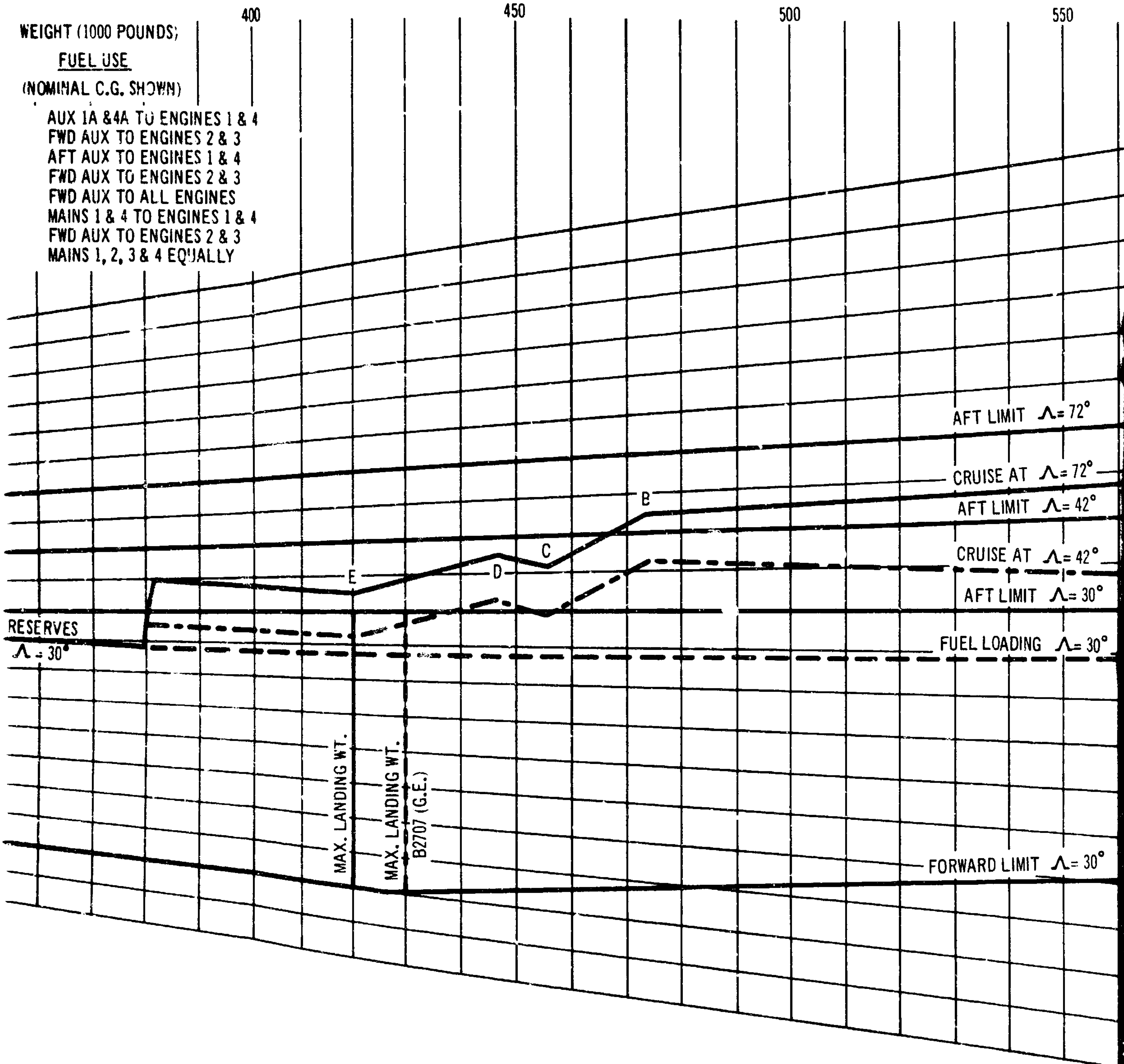


PAYLOAD

PASSENGERS AT 165 LB EACH

	SHOWN	CAPY.
1. FIRST CLASS	[illegible]	30
2. TOURIST – WINDOW	[illegible]	[illegible]
3. TOURIST – AISLE	[illegible]	[illegible]
4. TOURIST – REMAINING	[illegible]	[illegible]
CARGO (AT [illegible] LB CU FT)		
5. AFT	[illegible] LB	12040 LB
FORWARD		[illegible] LB

TA 13-10-66



B2707 (P & WA)

50,000 POUND PAYLOAD

3

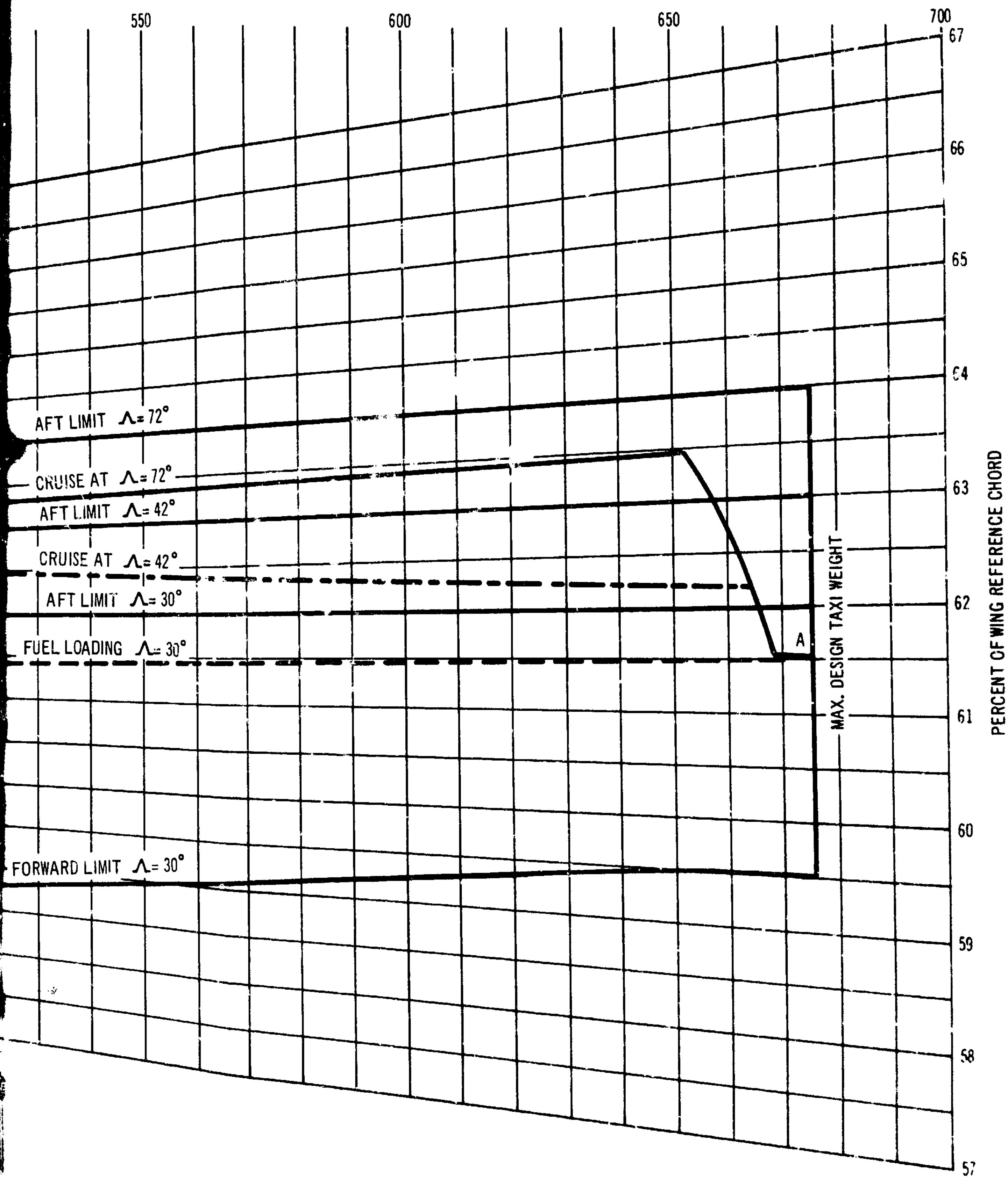


Figure 4-44. Balance Diagram

C

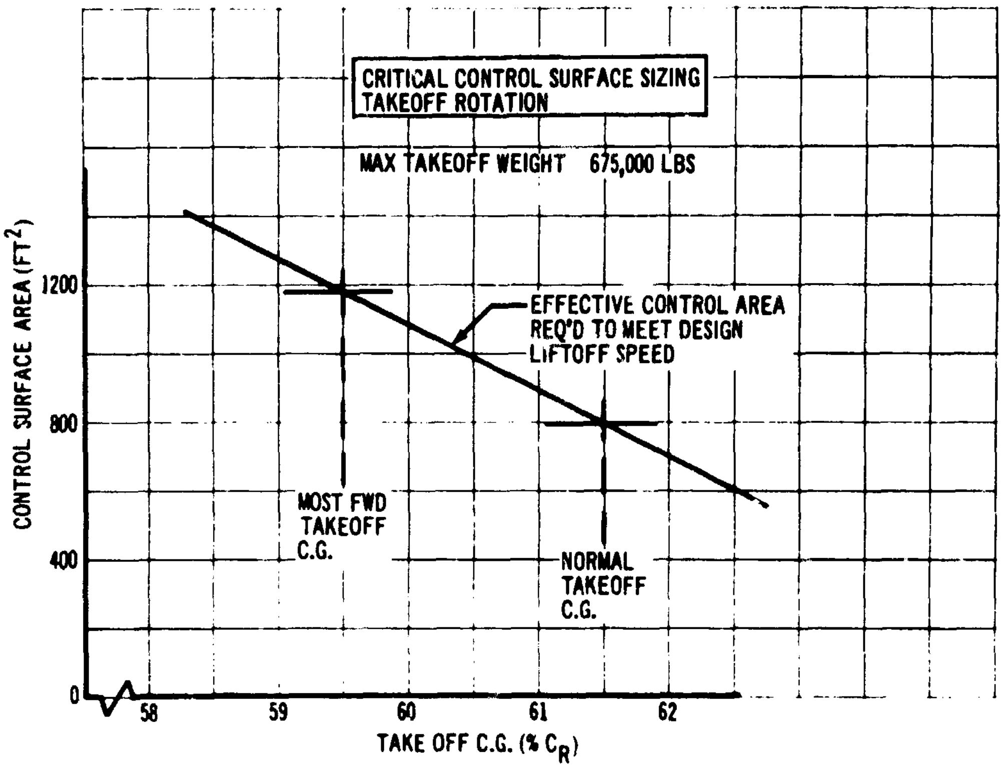


Figure 4-45. Pitch Surface Area Requirements

down. Fig. 4-62 shows typical visibility during cruise.

Articulation of the forward portion of the nose by a straight-forward linkage system permits adequate ground clearance, making taxi and ramp damage extremely unlikely. Further, the degree of articulation maintains pitot-static head and weather radar antenna alignment equivalent to that of supersonic cruise without complex correction or orientation systems.

Flat glass panels are used throughout to hold optical distortions to a minimum. Detail design of the forebody is such that it may be used at intermediate positions during subsonic flight with insignificant drag penalty.

The nose is operated by a dual electric motor drive system and free fall capability is provided. In the unlikely event of failure of all three of these systems to function, simulator studies have shown that adequate vision can be provided through the forebody windows for landing approach by increasing the speed by approximately 13 knots.

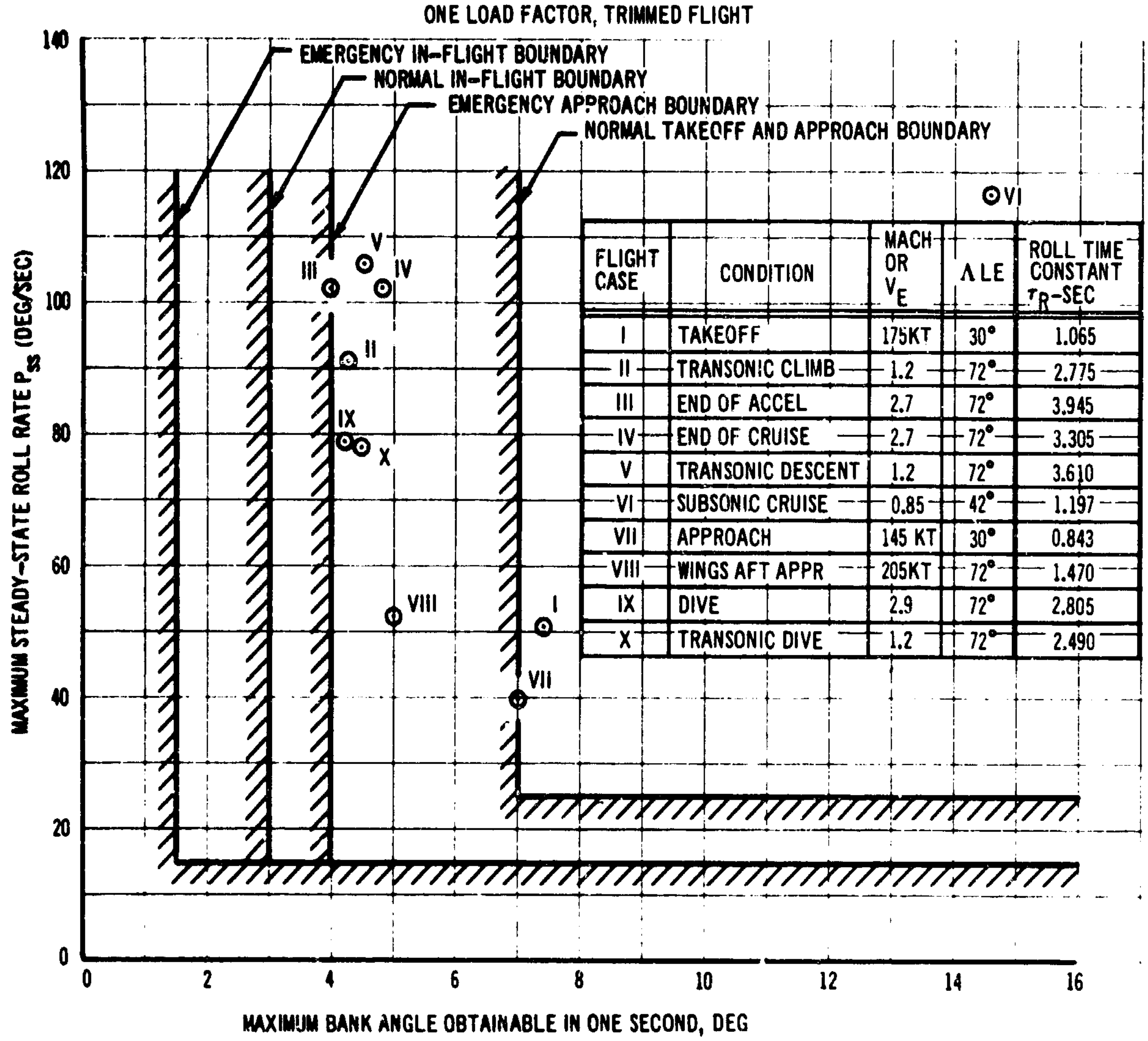
4.7 NOISE ALLEVIATION

Design integration during Phase II-C has improved both the external and internal noise characteristics of the B-2707.

4.7.1 Interior Noise

Typical external sound pressure levels are shown in Fig. 4-63. The internal noise environment resulting from jet exhaust noise generation has been reduced to a minimum over the occupied portion of the airplane by the aft placement of the engines and appropriate use of insulation.

Attention to equipment locations within the airplane greatly assists in maintaining a passenger cabin sound level which meets design guarantee levels. Equipment noise compliance level limits have been established based on installation positions in the airplane. Systems such as the air conditioning distribution system, which are prime interior noise sources, have been integrated into the airplane design with attention to noise level limitations. The air conditioning packs are located in the wing section and the duct air velocities have been limited for noise reduction purposes. As



FLIGHT CASE	CONDITION	MACH OR V_E	Λ LE	ROLL TIME CONSTANT τ_R-SEC
I	TAKEOFF	175KT	30°	1.065
II	TRANSONIC CLIMB	1.2	72°	2.775
III	END OF ACCEL	2.7	72°	3.945
IV	END OF CRUISE	2.7	72°	3.305
V	TRANSONIC DESCENT	1.2	72°	3.610
VI	SUBSONIC CRUISE	0.85	42°	1.197
VII	APPROACH	145 KT	30°	0.843
VIII	WINGS AFT APPR	205KT	72°	1.470
IX	DIVE	2.9	72°	2.805
X	TRANSONIC DIVE	1.2	72°	2.490

Figure 4-46. Roll Performance with Proposed Boundaries

an added noise reduction measure, equipment and systems components which could contribute to sound levels in inhabited areas, are installed on mounts which provide effective vibration isolation and reduce structure borne noise levels. The predicted interior sound levels resulting from these noise reduction measures are shown in Table 4-A.

4.7.2 Airport and Community Noise

The excellent low speed characteristics of the B-2707 due to the variable geometry wing, together with the high thrust loading and noise suppression capabilities of the propulsion system, provides the operator with great flexibility in adapting to various airport noise restrictions. Engine exhaust nozzle design has been influenced by noise suppression requirements. Slight modifications by the engine manufacturer in this area have been expanded by Boeing to achieve additional noise suppression. Boeing is providing a variable geometry sonic throat in the propulsion air inlet to eliminate fan or compressor noise from the inlet. This arrangement has resulted in an optimum design balance between noise and performance. With this additional noise suppression, the B-2707 will be able to meet FAA

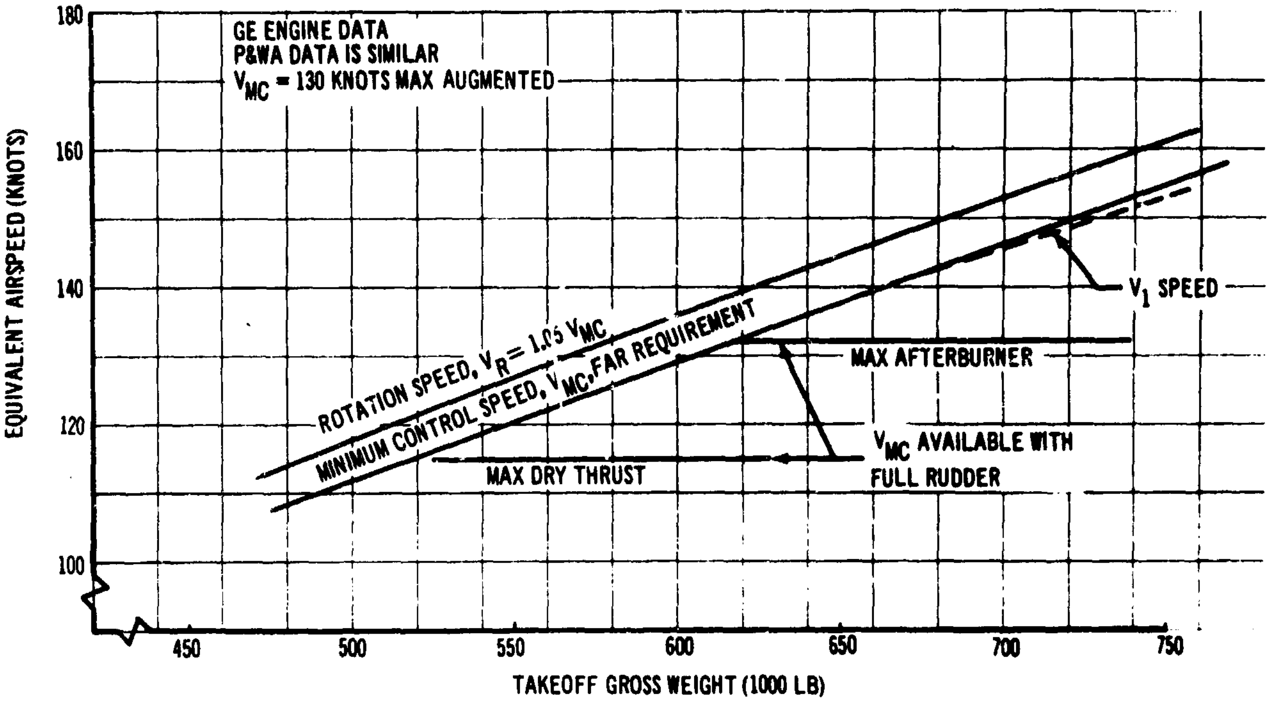


Figure 4-47. Takeoff Minimum Control Speeds

airport and community noise objectives for take-off, climbout and landing (see Table 4-B), and will maintain low noise levels during ramp and taxi operations. For additional details, see "Airport and Community Noise Program," V4-B2707-4.

Realizing the importance of further noise reduction, Boeing is continuing an extensive company-funded research and development effort to provide more effective means of noise suppression. A complete report of this work is included in Propulsion Report, V2-B2707-13.

4.7.3 Sonic Boom

Consideration of sonic boom has been fundamental in the design of the B-2707. The airplane configuration has been optimized to obtain the best sonic boom characteristics at all Mach numbers, commensurate with minimum drag and structural weight considerations. This is evidenced by the fact that despite increases in fuselage size for improved passenger accommodations, the airplane essentially meets the FAA objectives for domestic and international missions as summarized in Table 4-C. This sonic boom data is based upon flying the pressure altitude - Mach number profile shown in Fig. 4-64. The sonic boom overpressures directly under the flight path are shown as a function of ground distances on Fig. 4-65.

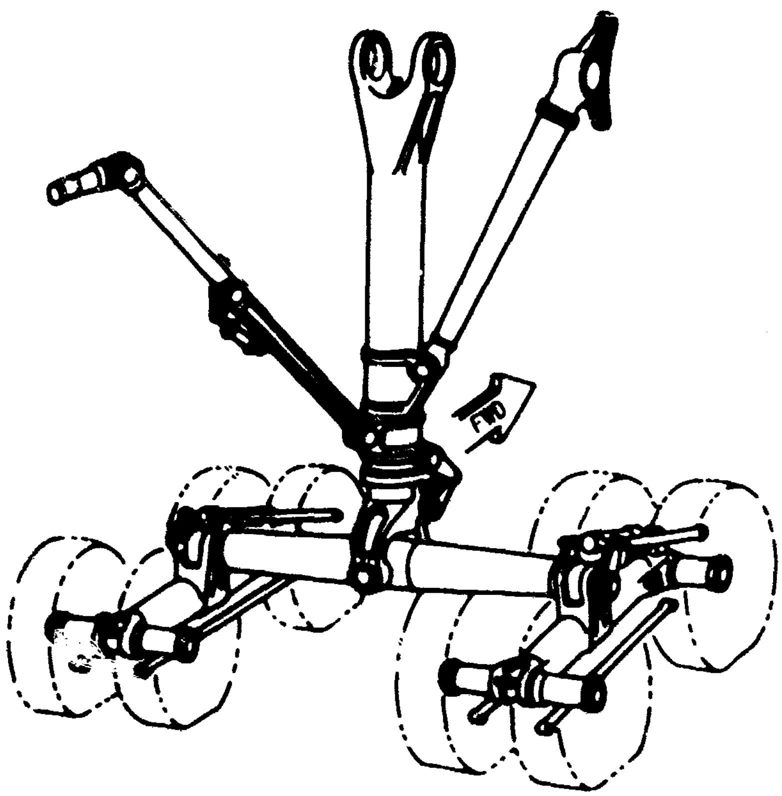


Figure 4-48. Two-Post Gear Arrangement

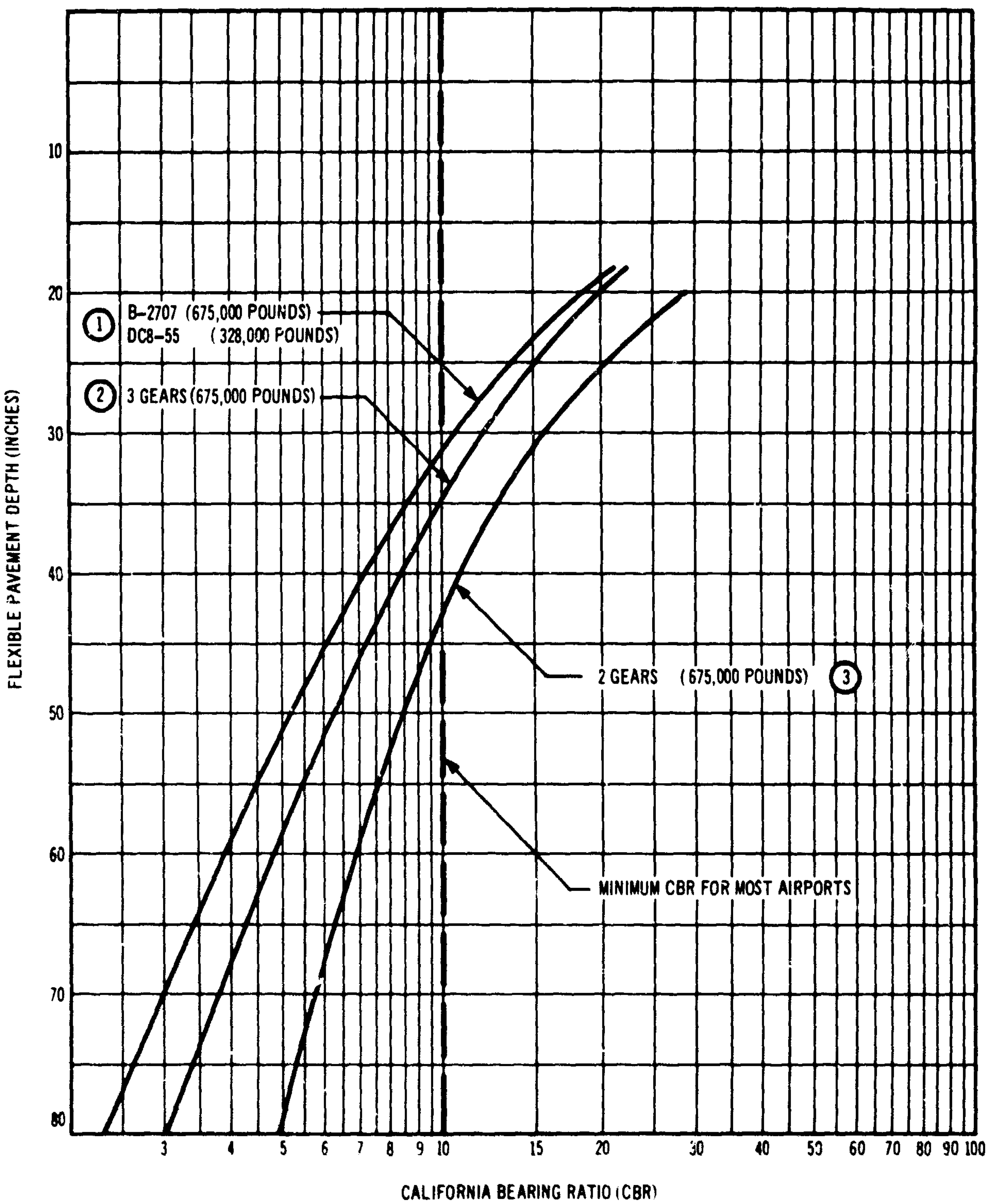


Figure 4-49. Flexible Pavement Depth Requirements (Corps of Engineers Procedures)

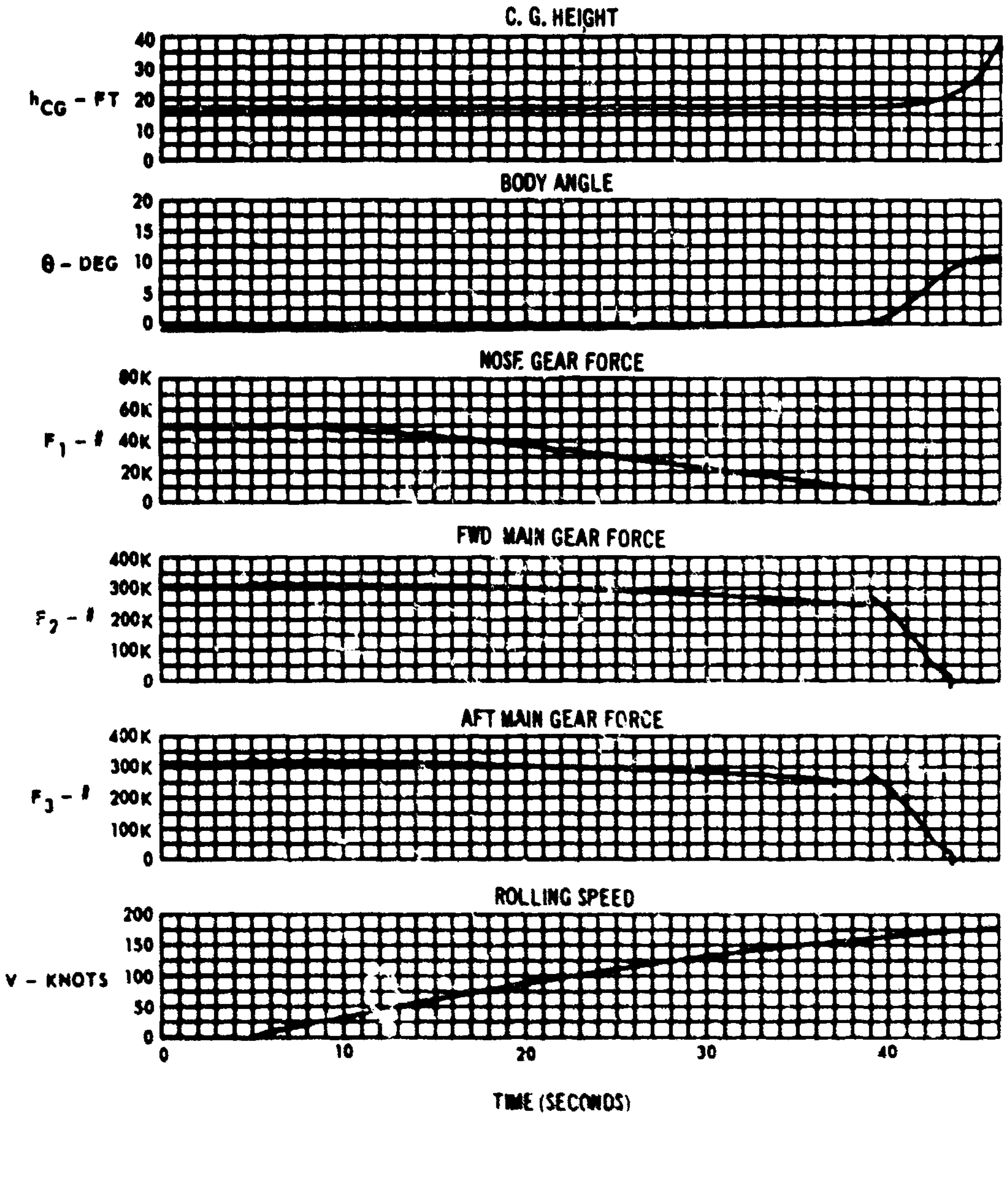


Figure 4-50. Landing Gear Dynamics - Takeoff

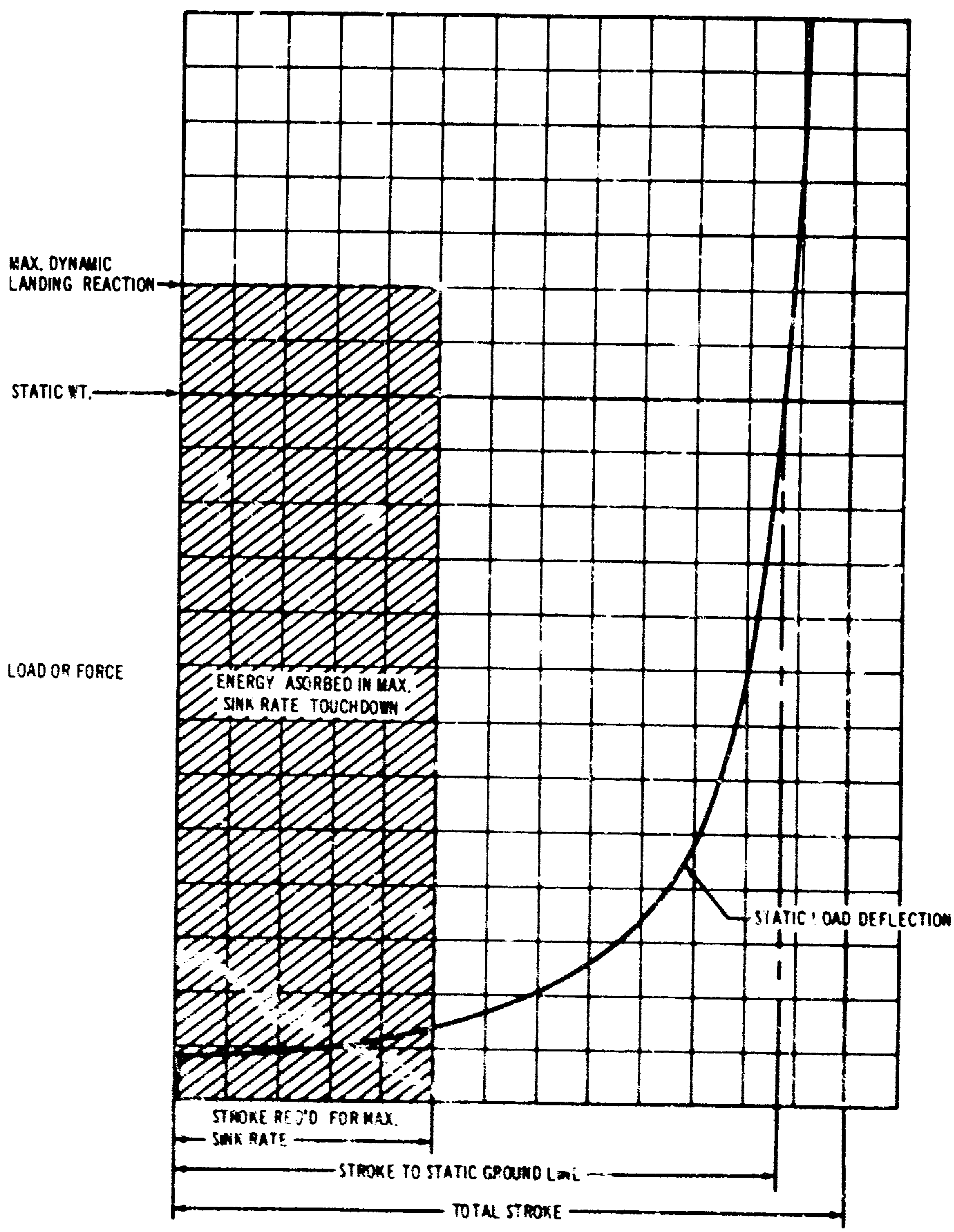


Figure 4-51. Typical Oleo Characteristics, Aft Gear

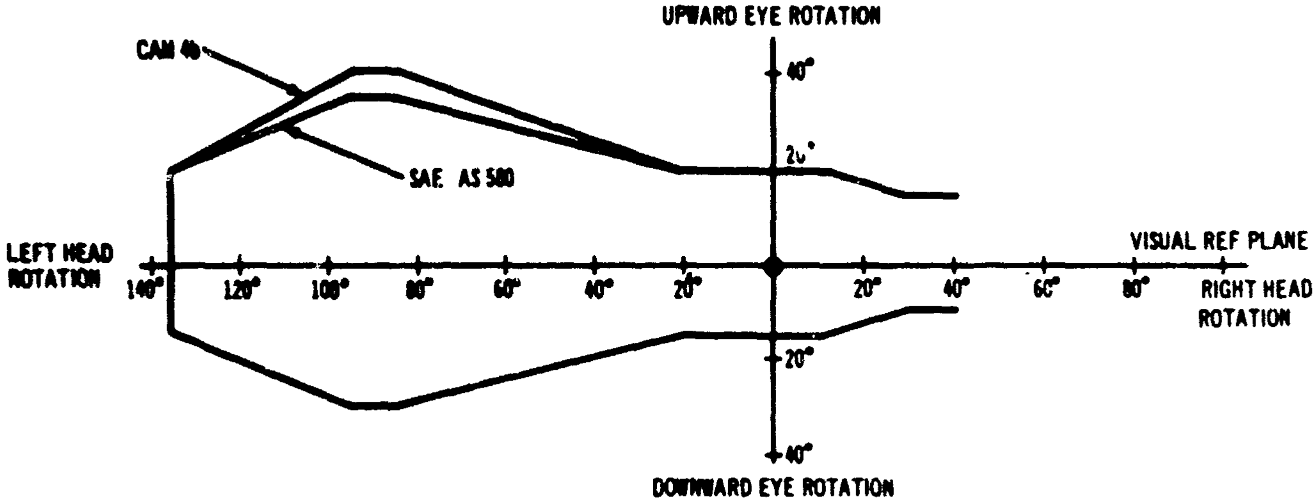


Figure 4–52. Vision Polar Objectives

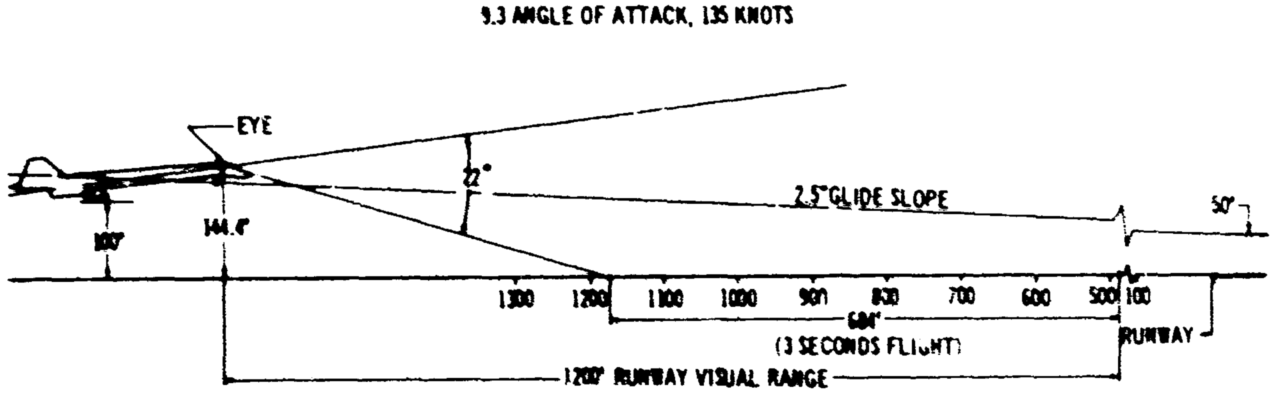


Figure 4–53. Runway Vision Requirement

FULL PAYLOAD AND RESERVES
GE 4 J5P ENGINE
θ = BODY ATTITUDE ABOVE HORIZON
$\theta = \alpha + \gamma$
γ = −2.5 GLIDE SLOPE

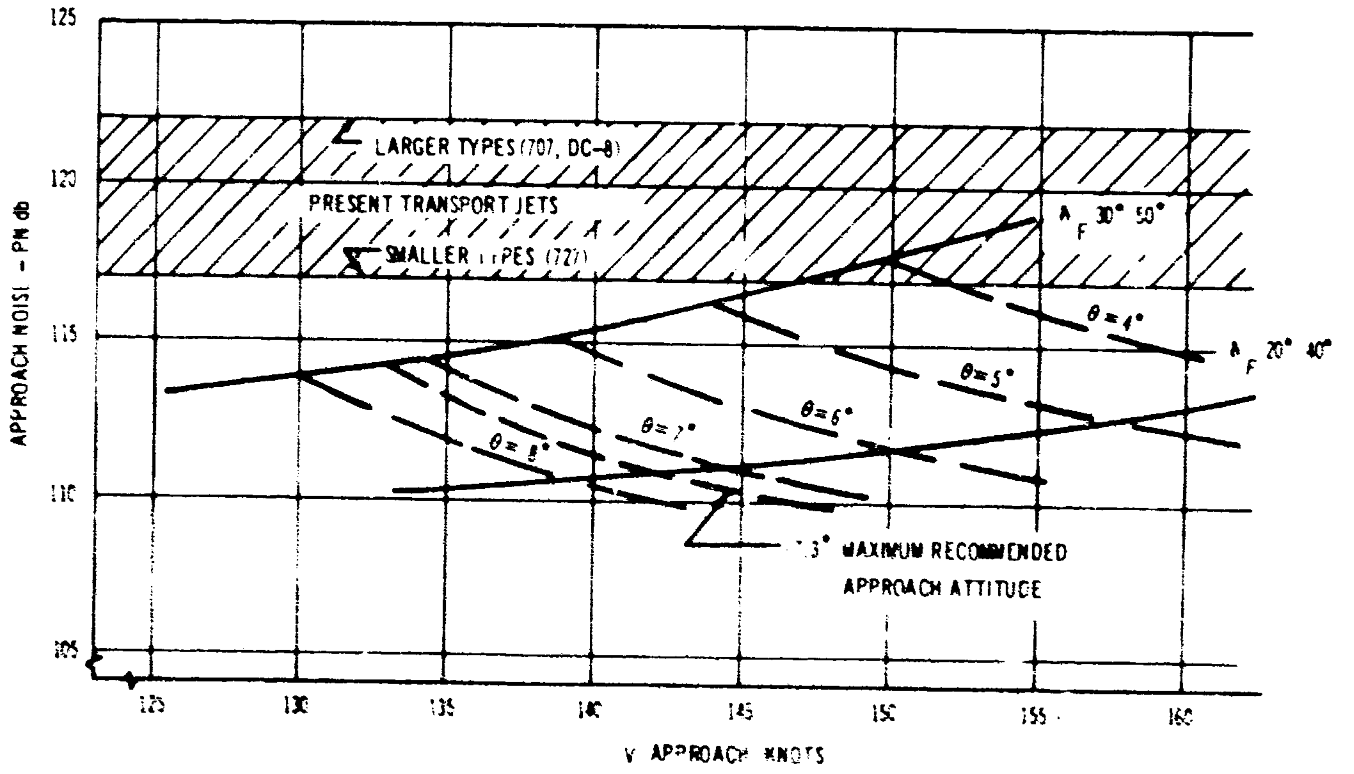


Figure 4-54. Typical Approach Noise − Velocity Trades

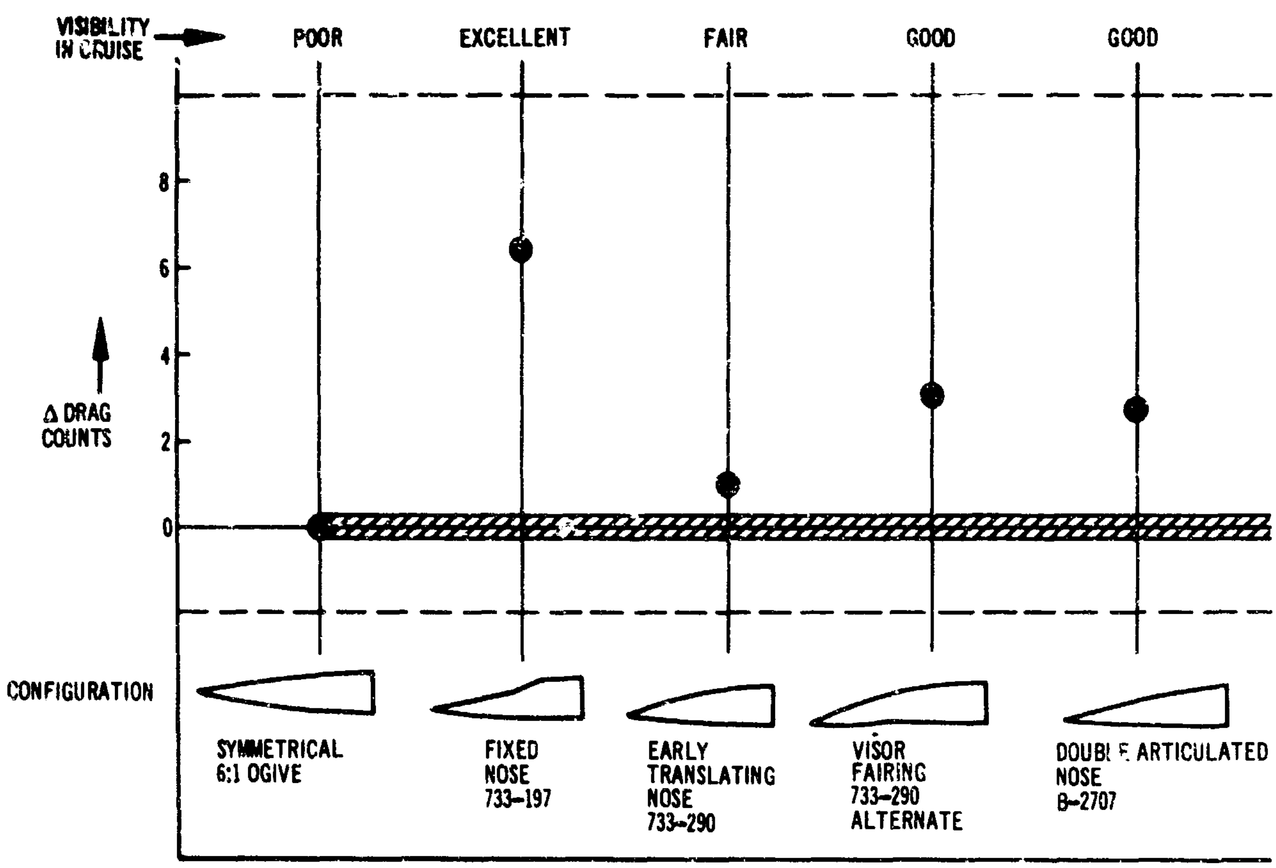


Figure 4–55. Forebody Configuration Development

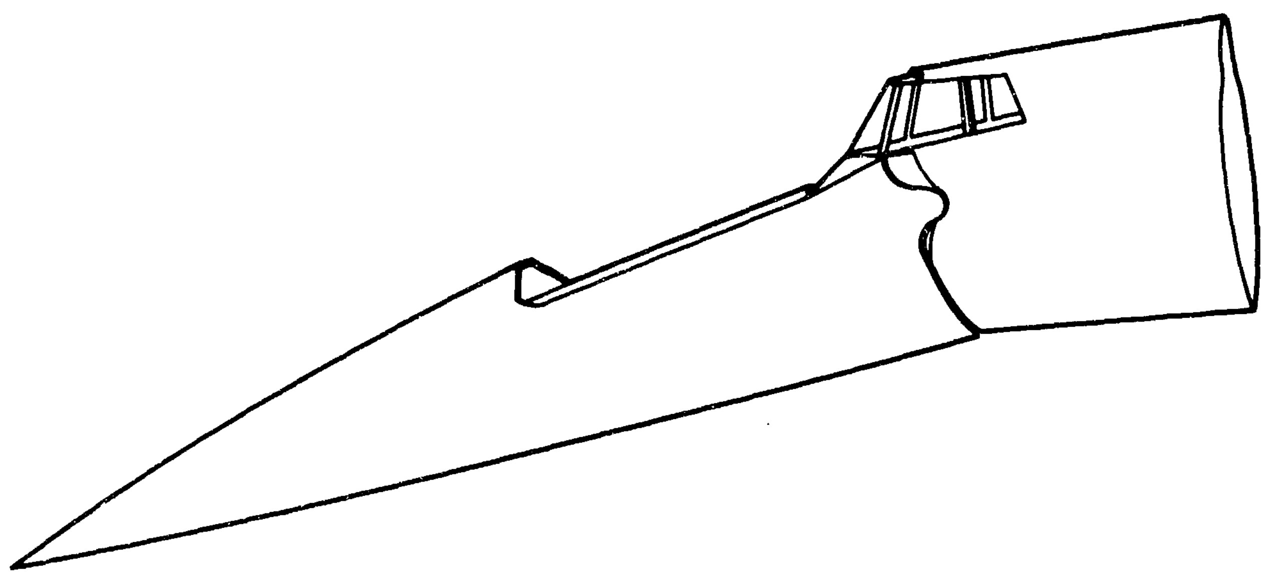


Figure 4-56. Visor Forebody

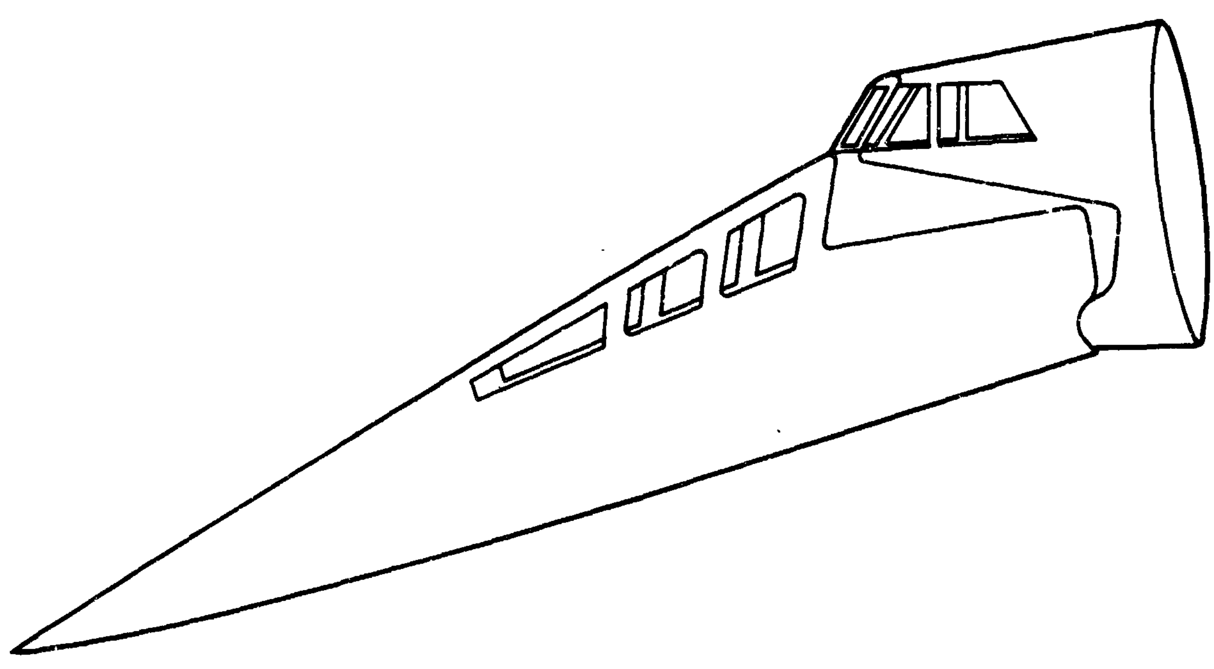


Figure 4-57. Rotating Forebody

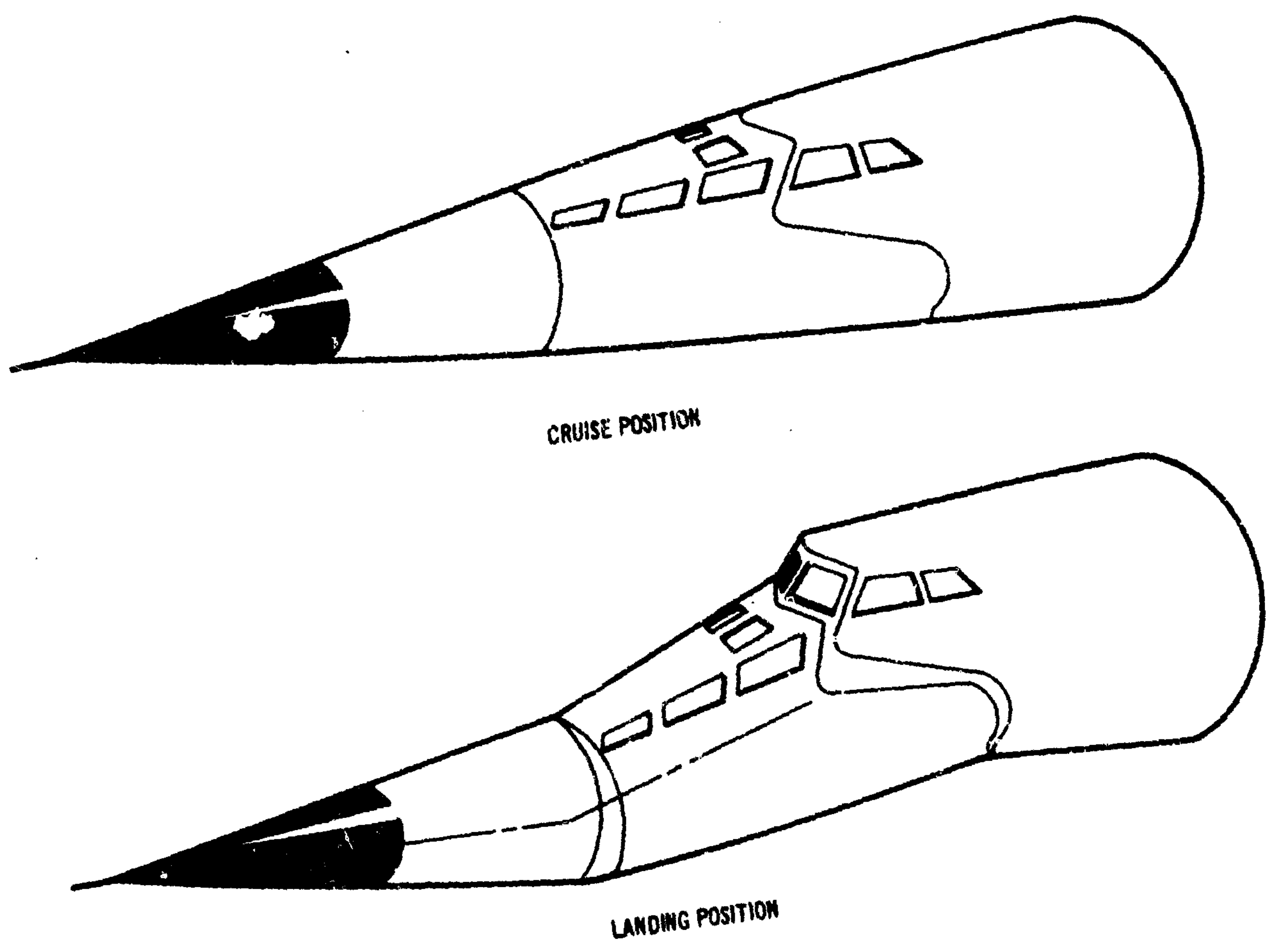


Figure 4-58. Landing Position

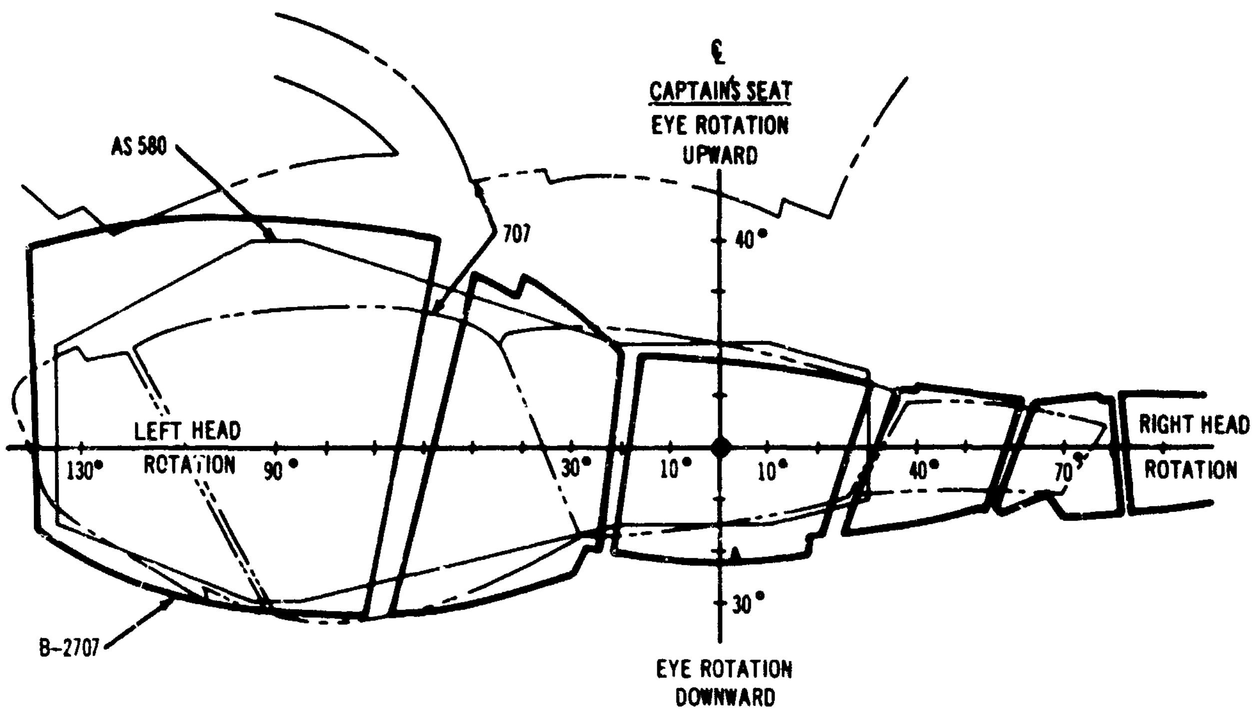


Figure 4-59. B-2707 Nose Down Vision Polar

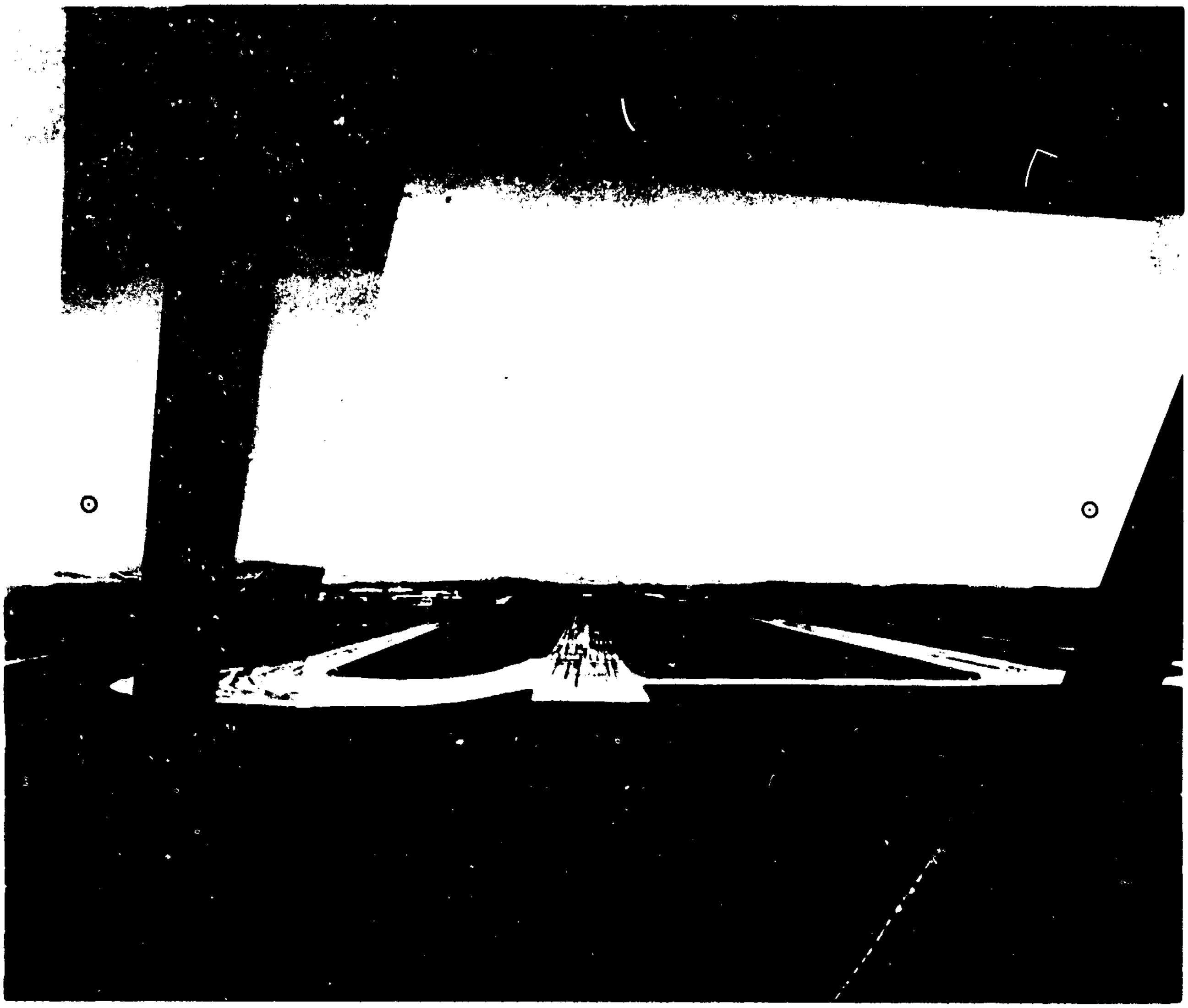


Figure 4-60. Approach Visibility

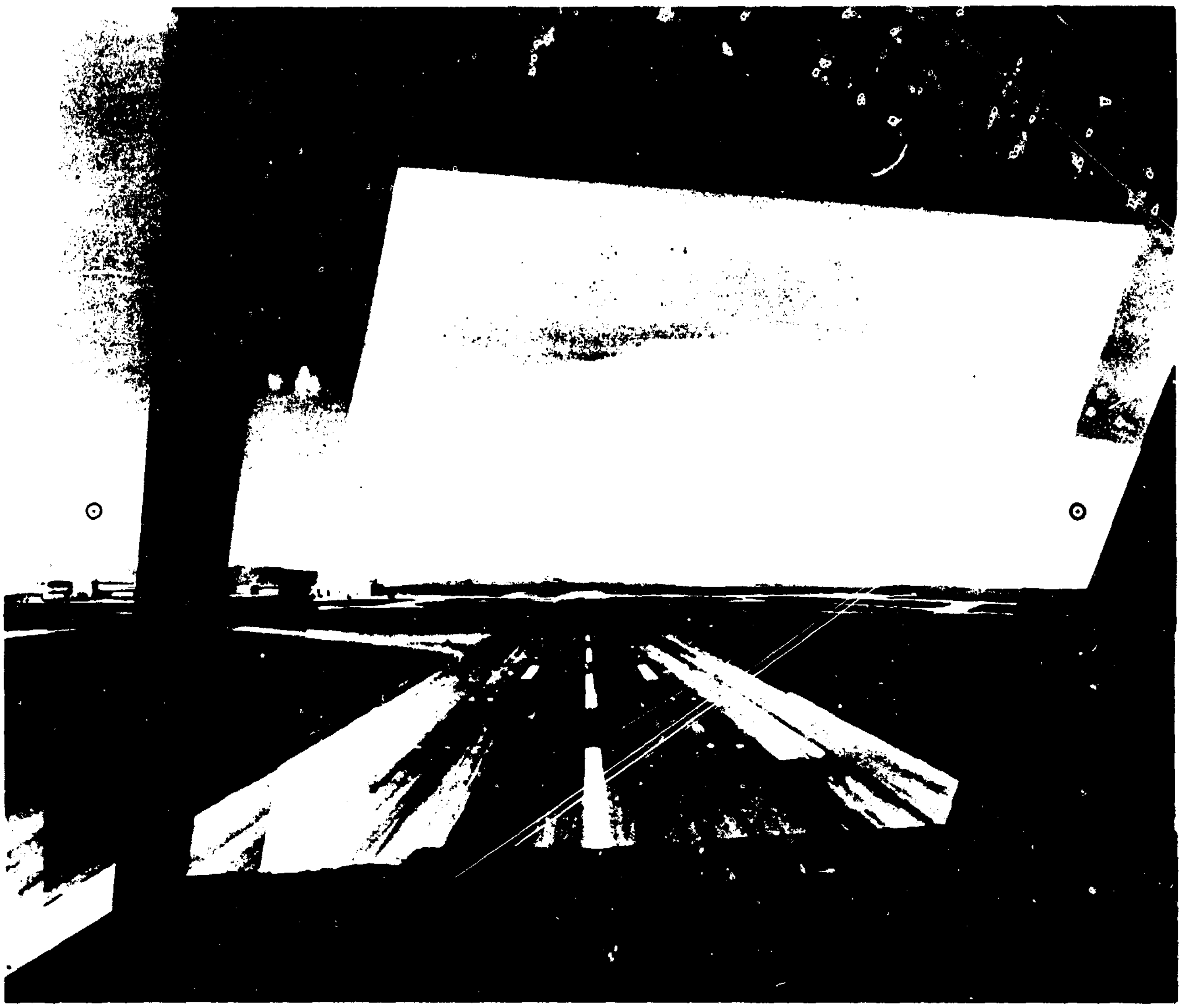


Figure 4-61. Touchdown Visibility

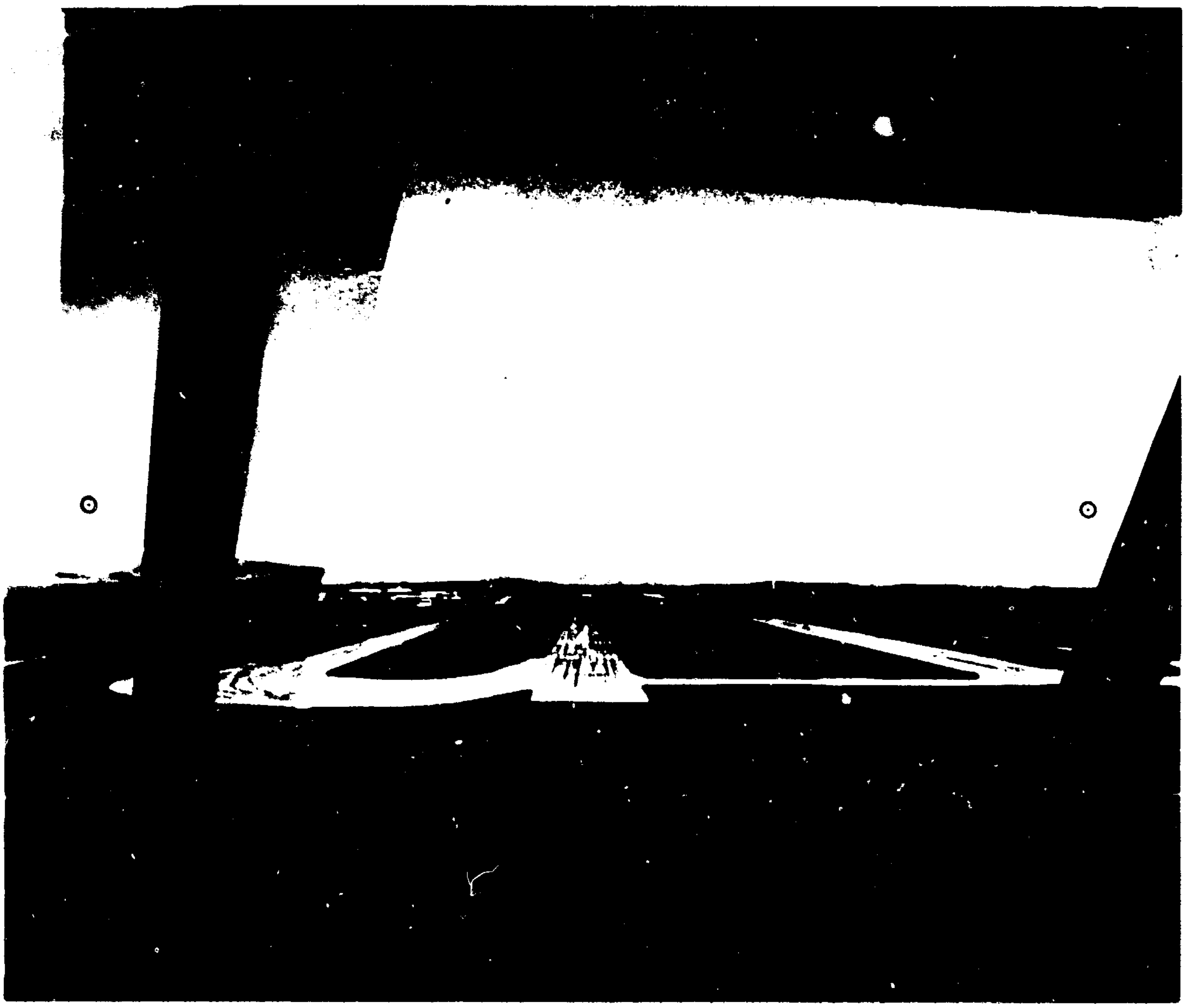


Figure 4-60. Approach Visibility

Figure 4-61. Touchdown Visibility

Figure 4-62. Normal Cruise Visibility

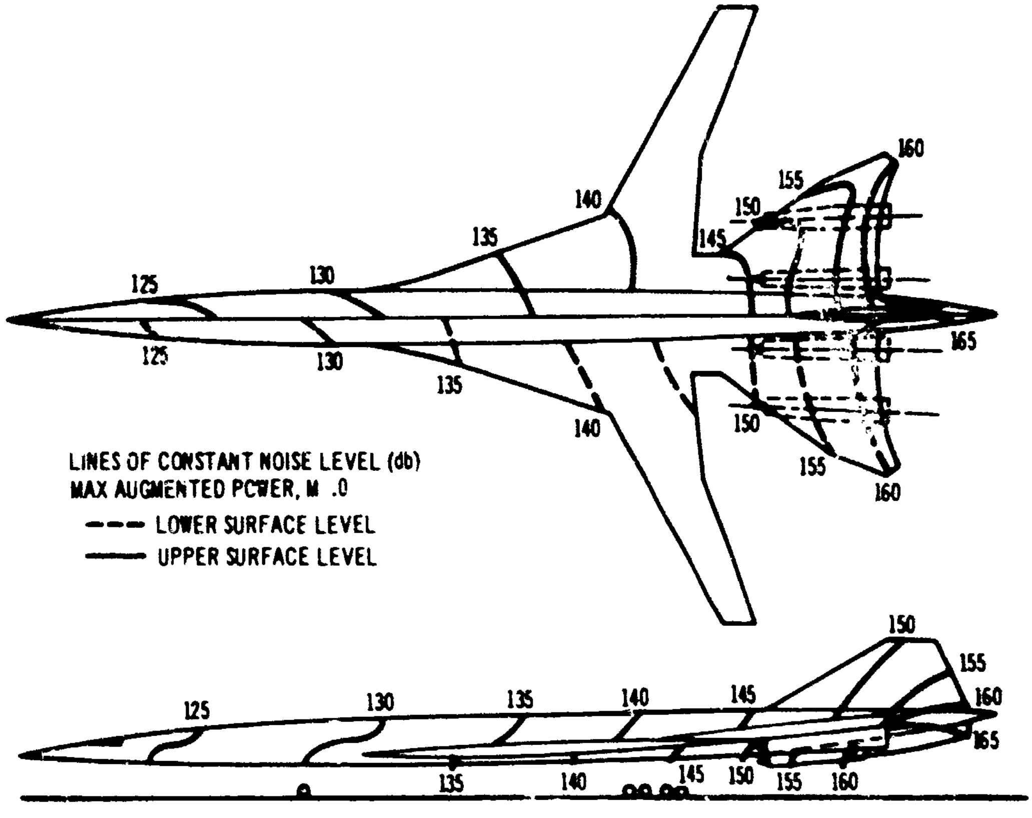


Figure 4-63. B-2707 Acoustic Environment

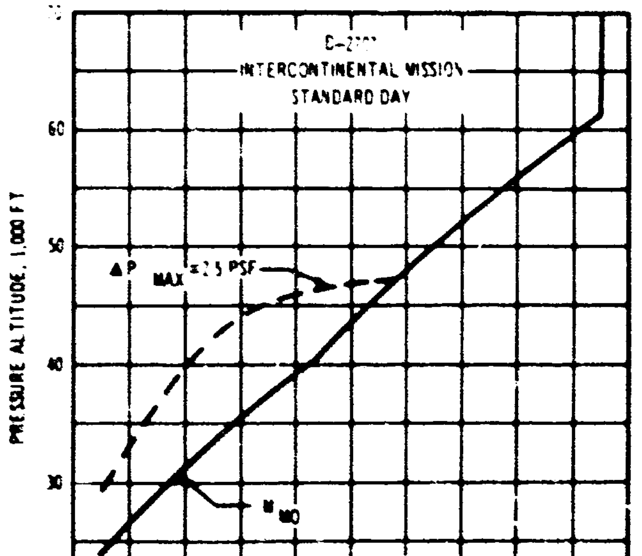


Figure 4-64. Comparison of Climb Schedules

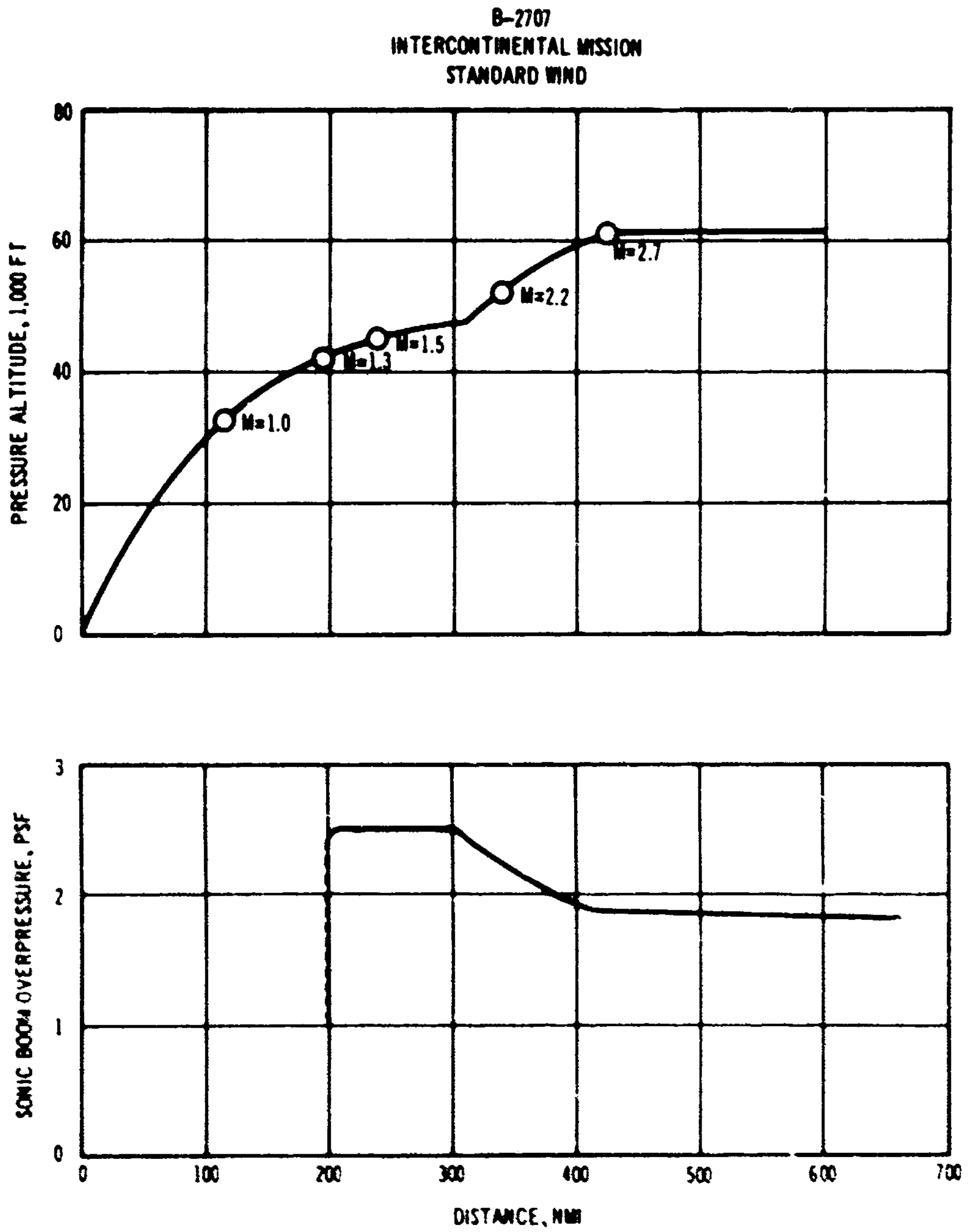


Figure 4-65. B-2707 Sonic Boom Under Flight Track

V2-B2707-1

Table 4-A. B-2707 Interior Sound Levels

B-2707 INTERIOR SOUND LEVELS						
	TAKEOFF MAXIMUM AUGMENTATION POWER			CRUISE 2.7M; 65,000 FEET		
		Boeing Guarantee			Boeing Guarantee	
	FAA Design Objective	GE G4/J5P Engines	P&WA JTF17A-21B Engines	FAA Design Objective	GE G4/J5P Engines	P&WA JTF17A-21B Engines
(dB RE: 0.0002 MICROBARS)						
Overall Sound Pressure Level (OA-SPL)	110	107	105	97	85	85
Speech Interference Level (SIL)	78	76	74	67	67	67

Table 4-B. B-2707 Airport and Community Noise With Boeing Jet Suppression Summary Table

ENVIRONMENT	NOISE LEVELS - PNdB		
	FAA OBJECTIVES	B-2707 (GE)	B-2707 (P&WA)
Airport	116	112	113
Community	105	98	103
Landing	109	108	110

Table 4-C. Effect of Sonic Boom on Airplane Performance

	B-2707 (GE)	B-2707 (P&WA)
Mission	International	International
Max Taxi Weight	6[illegible],000 LB	675,000 LB
Payload	50,000 LB	50,000 LB
Climb ΔP_{MAX}	2.50 psf	2.50 psf
Cruise ΔP_{MAX}	1.88 psf	1.87 psf
Range N. Mi.	3819	3738
Range St. Mi.	4396	4302

5.0 MOCKUP ACTIVITIES

A Mockup Plan for Phase II-C (July 1965 through December 1966) was released in December 1965, and indicates the types of mockups to be constructed during Phase II-C. Construction schedules are also indicated. The plan has been updated to reflect characteristics of the B-2707.

Some of the Phase II-C mockups, including the full scale mockup, have been completed. Others are scheduled for completion in December 1966. The completed mockups have aided configuration development, as well as communication of design concepts to the FAA, the airlines, and Boeing personnel.

Table 5-A lists all Phase II-C mockups, their status, and proposal documentation references that contain information about each mockup.

The mockup plan for Phase III is described in Boeing document Mockup Plan V2-B2707-2. This document is a part of the Boeing proposal submittal.

Table 5-A. Phase II-C Mockup References

MOCKUP	STATUS	REFERENCE DOCUMENT	REFERENCE SECTION
Passenger Cabin Interior	Complete	V2-B2707-11	7.0
Partial Cabin Without Windows			
Full Length Cabin With Windows			
Lavatory			
Anticollision Beacon Installation	Complete	V2-B2707-10	2.2.8
Outboard Wing Leading Edge	In Work	V2-B2707-6-2	2.2
Wing and Empennage	In Work	V2-B2707-6-2	2.2
Forebody and Flight Deck	Complete	V2-B2707-11	6.0
Wing-Body Joint	Complete	V2-B2707-6-2	2.3
Main Landing Gear	In Work	V2-B2707-6-2	2.5
Wing Pivot	Complete	V2-B2707-6-2	2.2
Power Plant Installation	Complete	V2-B2707-12	4.3
Accessory Drive & Environmental Control System Installation	Complete	V2-B2707-10 V2-B2707-11	1.6 9.6
Electrical/Electronics Racks	Complete	V2-B2707-10	2.6
Cargo Provisions	Complete	V2-B2707-11	7.0
Engine Inlet	Complete	V2-B2707-12	3.1
Full-Scale Airplane	Complete		

CONTENTS

6.0 GROWTH POTENTIAL

6.1 INTERNATIONAL AIRPLANE GROWTH

The design of the B-2707 is capable of exceeding the 4,000 st mi range objective with a 60,000 lb payload using FAA mission rules. However, mission rules used by some of the international carriers include summer day atmospheric conditions, and conservatisms in specific fuel consumption, in empty weight, and in fuel reserves. When these considerations are included, the available payload is reduced considerably. For example, the payload for a Paris-New York flight is reduced to 40,000 lbs. (Fig. 6-1.)

Improved payload capabilities under airline type rules can be achieved with increased gross weights. Studies of the B-2707 at higher weights indicate that a considerably increased payload-range capability could be obtained at a gross weight of 750,000 lb as shown in Fig. 6-2. At this higher gross weight, however, the sonic overpressure will be higher (3.0 psf). This capability may be obtained with little change to the airplane. Fuel volume would be increased by deepening the body about nine in. forward of the main spar and extending the tail cone tank by about 100 in. Landing gear tire size and truck geometry can be increased at a small cost in drag to maintain comparable runway pressures. Holding the transonic acceleration to acceptable limits, the climb sonic boom overpressures would be approximately 3.0 psf and the initial cruise overpressure would be approximately 2 psf. FAR field length, on an 86°F day, would be 10,500 ft. The second segment climb slope is double the required

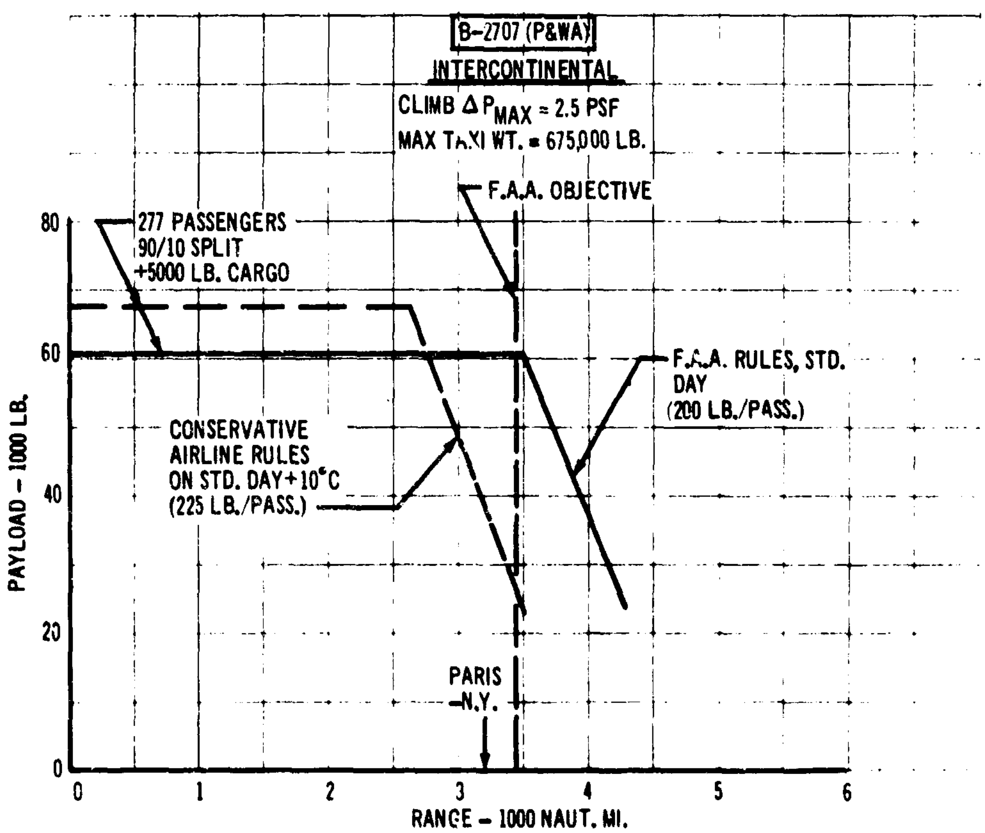


Figure 6-1. Range Capability

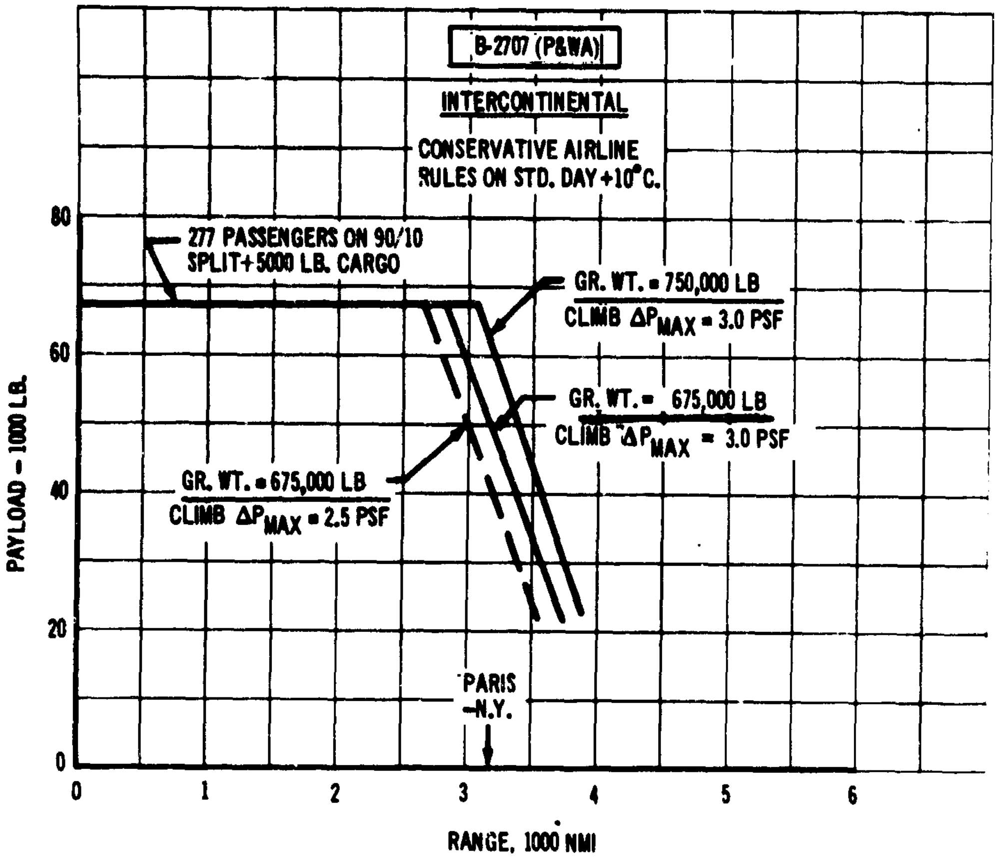


Figure 6-2. Range Capability

0.03. Lift-off speeds would increase to 179 knots and community noise to 110 PNdb. There is little difference in airplane performance using either the GE, or P&WA engines currently being proposed.

Section 6.3 discusses growth within the various technology areas that can be expected within the life span of the supersonic transport. As an example of combining improvements in the several areas noted therein, an increase in gross weight to 825,000 lbs (with an attendant increase in payload/range) is possible about five years after production of the initial production aircraft because of a 12 percent increase in thrust rating. There will also be a two percent increase in inlet efficiency, and a four percent improvement in engine specific fuel consumption. The range will improve from approximately 2,800 to 3,400 nmi for a full payload as shown in Fig. 6-3. Because of flap improvements, the low speed performance would be approximately the same as for the 750,000 lb version described in Par. 6.1.1.

6.2 DOMESTIC AIRPLANE VERSIONS

The capabilities of the B-2707 operating on domestic routes have been examined. A number of domestic versions have been studied, all based upon the 277 passenger international airplane.

Two-hundred sixty-one passengers (20 percent first class and 80 percent tourist) are accommodated in the same cabin space as the international version. Various interior arrangements are shown on Fig. 6-4.

The design ramp weight is 575,000 lbs, compared to 675,000 lbs for the international airplane. The structural weight has been reduced (because of the lighter ramp weight) by employing lighter gage structural material where possible, and by removing excess material from major components such as forgings and castings. The structure has not undergone a major redesign program. The same engines are employed for both the domestic and international versions. As with the international version, both GE and P&WA engines are compatible with the domestic aircraft.

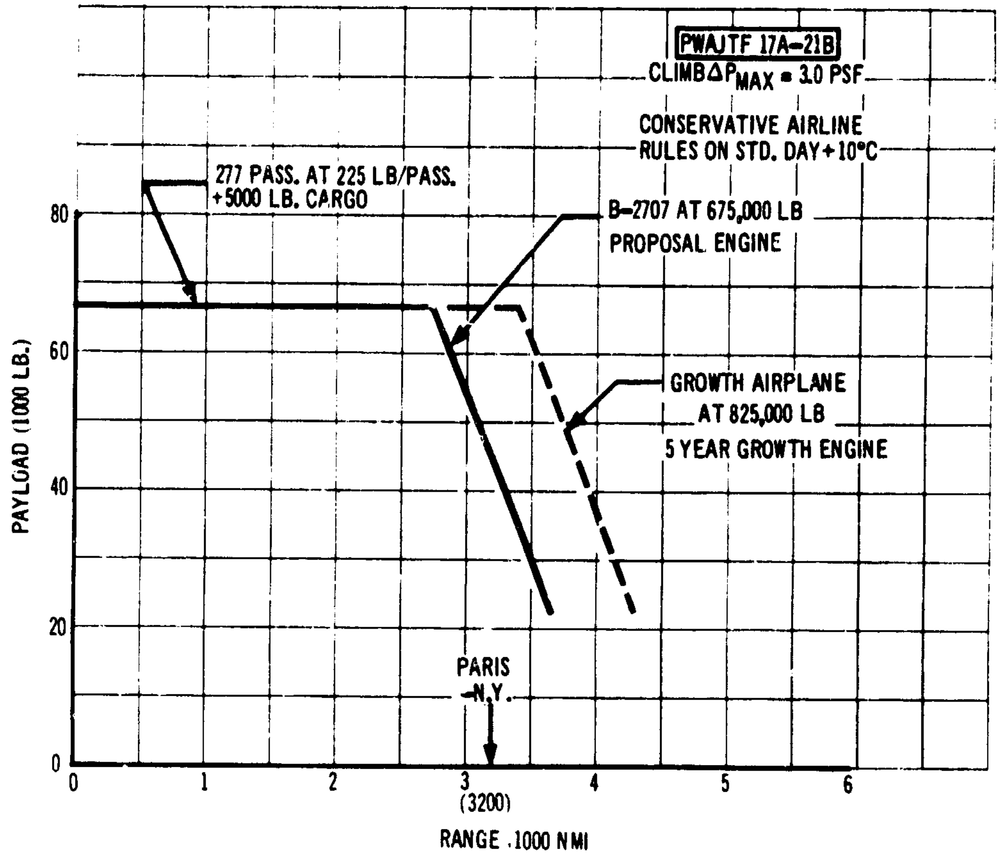


Figure 6-3. Intercontinental Growth in Five Years

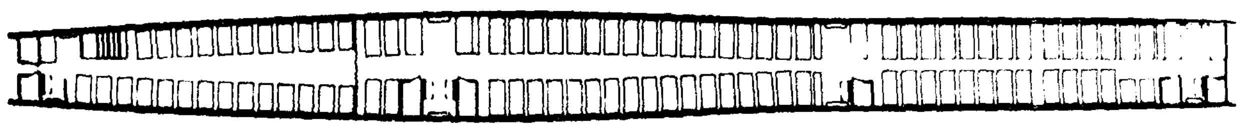
Payload-range capabilities of all of these versions are essentially the same (Fig. 6-5). Takeoff distances (Fig. 6-6) are shorter than those possible with the international version because of the reduced takeoff weight. Landing distances are also shorter (Fig. 6-6), because of the lighter landing weights. Lower flight weights also account for lower sonic boom characteristics. Sonic boom overpressures for the domestic versions are limited to two psf.

Extension of the passenger compartment into the aft cargo area permits increased payload possibilities as shown in Fig. 6-7.

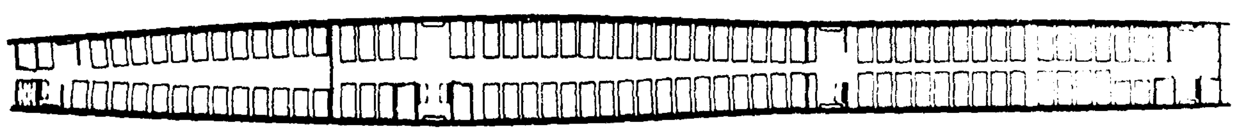
A description of all of these arrangements is contained in Systems Report Document V2-B2707-11, - Part B (Passenger and Cargo Provisions, Sec. 7.0).

Certain changes to the body to further tailor it to the domestic operation are possible which may interest some airlines more than the airplane previously described. Wind tunnel tests have been conducted on large double aisle bodies capable of carrying 300 to 350 passengers. These bodies will result in a small cost in drag and weight. By adding about 10 ft to the present length, increasing the maximum cross section to eight abreast, and using the "one seat from the aisle concept," it is possible to get 312 passengers (a domestic split of 20 percent first class - 80 percent tourist) into such a body as shown in Fig. 6-8.

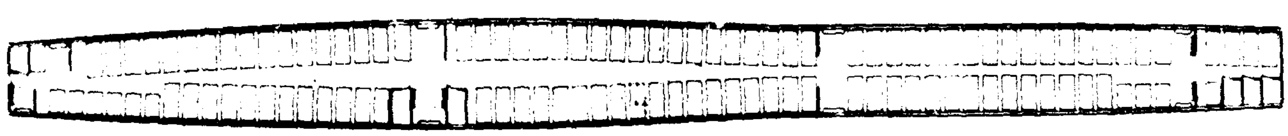
It is estimated that five years after initial production, growth engines would be available. The domestic airplane could take off at approximately 600,000 lbs, and operate at a lower sonic boom and a lower direct operating cost. Figure 6-9 shows the payload-range characteristics of the initial and growth versions. Although this figure compares characteristics for the P&WA engine, similar performance levels are available with the GE engines. A probable benefit for this type of body is a lower sonic boom level that for the six-abreast standard body as indicated by Fig. 6-10. Even though the



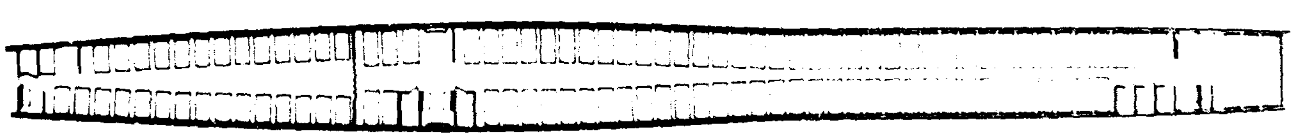
246 PASSENGER DOMESTIC MIXED DELUXE
(50 FIRST CLASS AND 196 TOURIST)



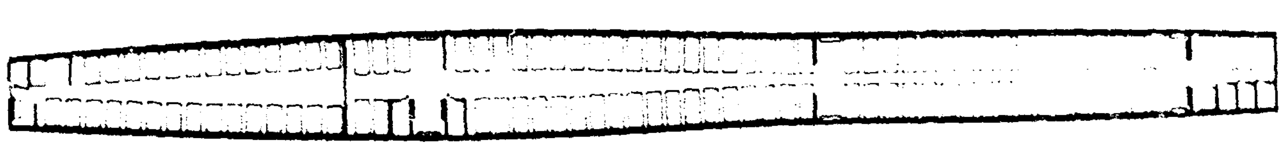
261 PASSENGER DOMESTIC MIXED
(50 FIRST CLASS AND 211 TOURIST)



317 PASSENGER DOMESTIC TOURIST



293 PASSENGER DOMESTIC MIXED
(56 FIRST CLASS AND 237 TOURIST)



289 PASSENGER DOMESTIC MIXED
(56 FIRST CLASS AND 233 TOURIST)

Figure 6–4. Domestic Interior Arrangements

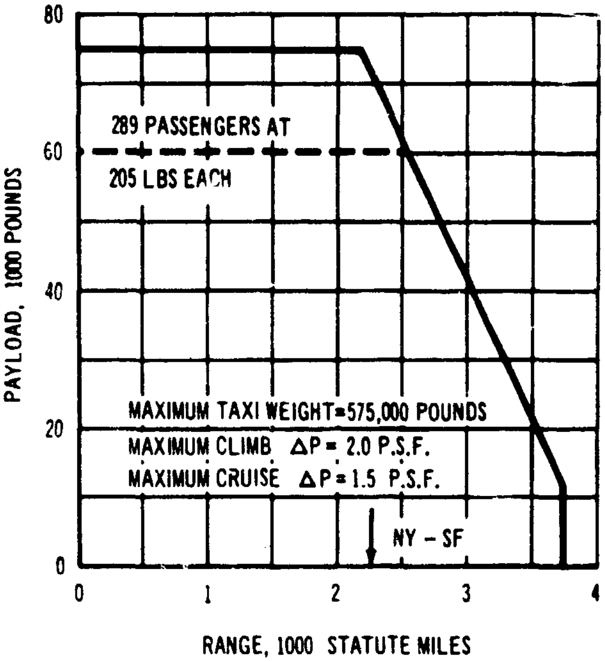


Figure 6-5. Payload-Range Capabilities (Domestic)

maximum cross section of the body is greater, the shape is more favorable. More comprehensive discussions of the domestic versions are contained in Aerodynamic Design Report V2-B2707-3, and Economic Summary V7-B2707-1.

6.3 TECHNOLOGY GROWTH

During the process of developing the prototype and production airplanes, improvements that will increase the efficiency of the supersonic transport will become available. In addition, applied research, both at Boeing and in various government agencies, will continue to improve the state of the art. These improvements will be incorporated into the airplane, as they have in the past, at model changes.

6.3.1 Aerodynamics

Large gains in supersonic cruise lift-drag ratios are not likely without major configuration changes. Continuous progress is being made in high lift flap system design. It is important to understand the value of a high lift flap system to growth versions of an airplane. Generally a flap research and development program conducted after initial production can provide low speed aerodynamic improvements that will allow growth in takeoff weight without deterioration in low speed performance. The incorporation of boundary layer control flaps might also result in a large improvement of the low speed performance.

6.3.2 Structures

It is expected there will be many areas where improvements can be made because of the relative newness of the supersonic transport. Additional knowledge of tanks, sealants, primary structural fasteners and allowables should permit a reasonable growth in the airplane structure.

For example, past and projected growth trends in the mechanical properties of titanium alloys are shown in Fig. 6-11. Values are shown for two growth rates at room temperature. Elevated temperature properties should have the same projected growth rate. The current allowable of 157,000 psi is predicted to increase to 186,000 psi by 1986. This prediction is considered reasonable on the basis of development test data currently being obtained in the range of 190,000 psi. This increase in allowable can be used to reduce the weight of the compression material in the airplane. Reductions in the operating empty weight of the airplane due to the projected increase in material allowables are shown in Fig. 6-12.

6.3.3 Airplane Systems

A review of airplane systems has been made to anticipate the likely changes necessary to keep pace with the added capability required. Most of the current systems have some stretch in their design, and it is anticipated that relatively minor changes will be required to increase their capability. State of the art improvements in the equipment would be expected to provide the large part of the additional capability at a minimum of weight change.

6.3.4 Propulsion

6.3.4.1 Inlet

The supersonic inlet development program, started prior to 1958, has seen a marked increase in inlet recovery and a decrease in weight due to several technology advancements. Fig. 6-13 illustrates the trend of increased inlet recovery with the important technology advancements highlighted. Fig. 6-14 compares the change in inlet dimensions (proportional to inlet weight) versus time, including the advances made to accomplish this trend.

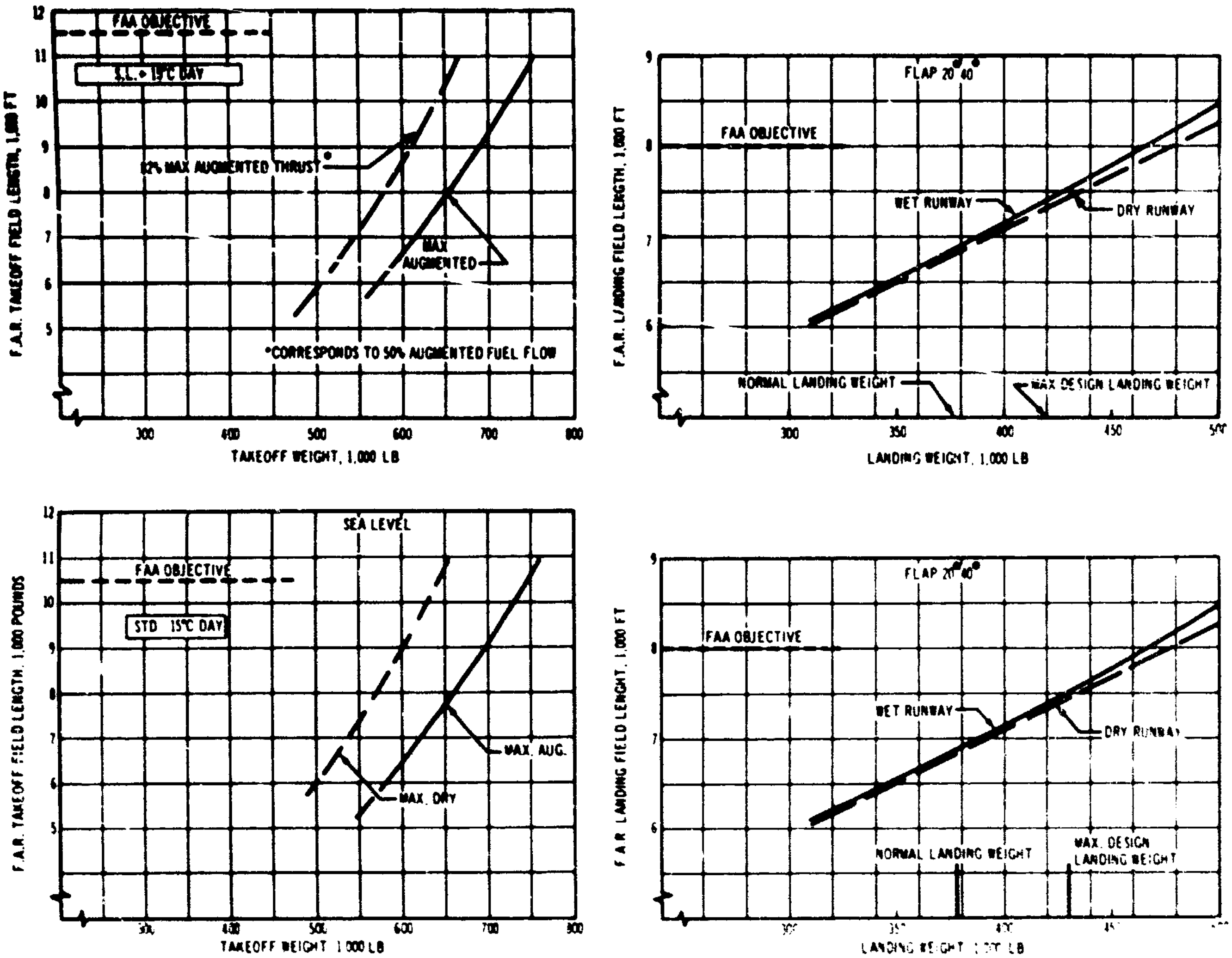


Figure 6-6. Takeoff and Landing Distances (Domestic)

6.3.4.2 Engines

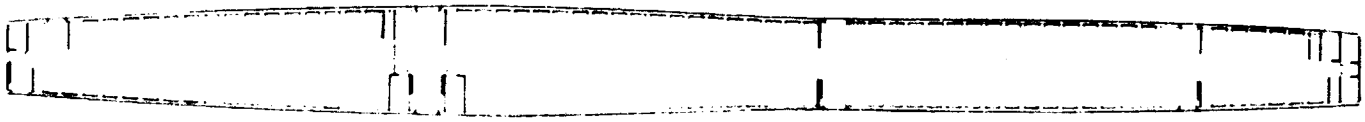
(a) Thrust-to-Weight Ratio

The takeoff and acceleration characteristics of a particular engine cycle are best evaluated on a thrust per lb of engine (F_N/Wt) basis. Advances in weight technology through higher compressor and fan stage loading and higher heat release burners can be added to increased airflow capability and pressure ratio, producing substantial gains in thrust with small increases in engine weight. Fig. 6-15 illustrates the trend of increased F_N/Wt, with several commercial and military engines singled out. Turbine inlet temperature growth is illustrated as a trend in Fig. 6-16 comparing temperature with time for turbine blades, with and without cooling. Again, several engines are shown to substantiate this trend. The growth in turbine temperature must be accompanied by advances in turbine metal technology and increased cooling effectiveness.

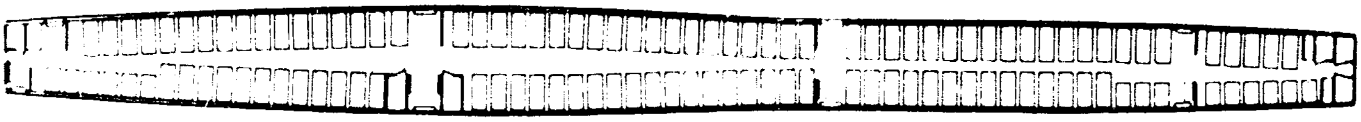
(b) Cruise SFC Improvements

Fig. 6-17 illustrates the trend of cruise SFC for supersonic and subsonic engines. The trend for subsonic engines is attributable to higher bypass ratios in conjunction with higher turbine-in temperature. For the supersonic engines, the main contributing factor is turbine-in temperatures.

For more detailed description of technical factors influencing the growth of the turbojet and turbofan cycles, and historical and projected

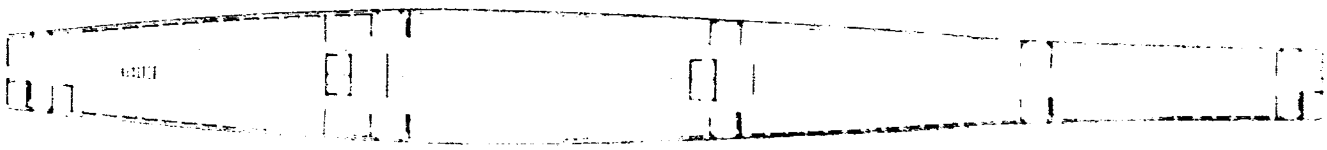


298 PASSENGER DOMESTIC MIXED
(64 FIRST CLASS AND 234 TOURIST)



330 PASSENGER DOMESTIC TOURIST

Figure 6-7. Domestic Interior Arrangements (Extended Cabin)



(61 FIRST CLASS AND 251 TOURIST)

Figure 6-8. 312 Passenger Domestic Mixed (8 Abreast)

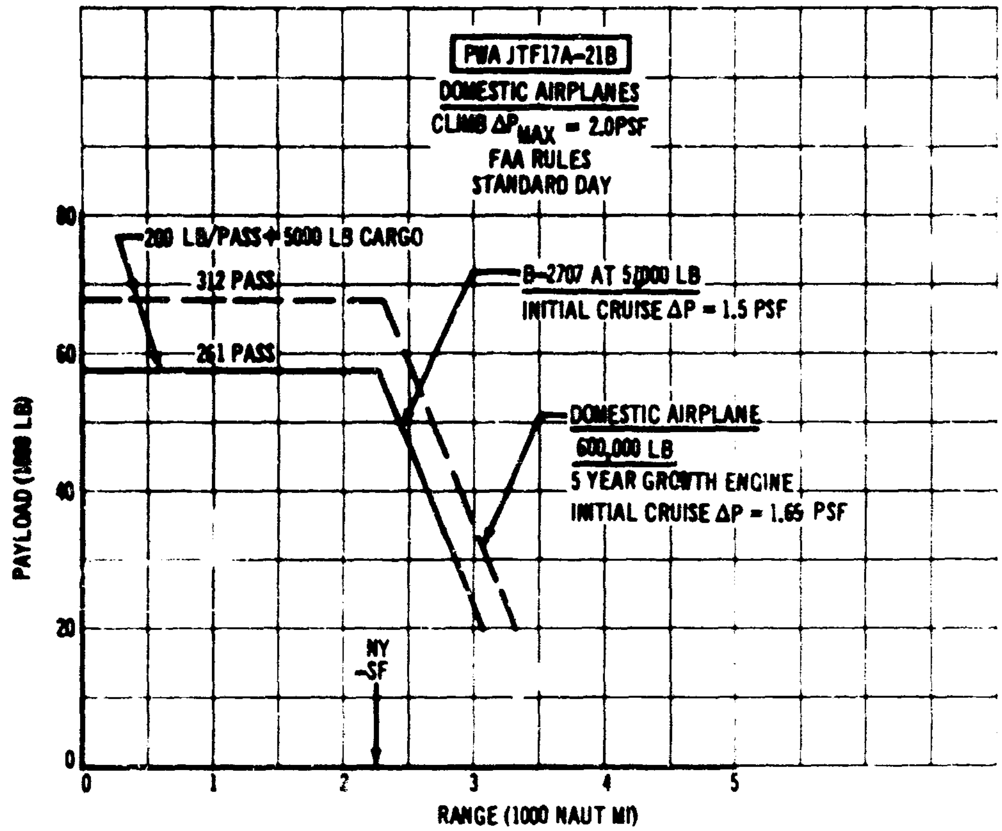


Figure 6-9. Domestic Airplane Performance

growth of the GE and P&WA engines, refer to Propulsion Report V2-B2707-12, - Part A, and Propulsion Report V2-B2707-14, - Part C. These reports are a part of the proposal submittal.

(c) Engine Noise Suppression

A Boeing noise suppression design has demonstrated 10-15 PNdb of suppression during test on a J-75 engine. The noise suppression equipment consists of a multi-tube exhaust nozzle and acoustic lined ejectors, attached to the engine exhaust. The principle of suppression is unusual because the jet noise maximum intensity is shifted to higher frequencies which are absorbed by the lined ejector. Attainment of these suppression levels in an afterburning or duct burning system with a convergent-divergent nozzle has yet to be demonstrated. However, the principle has been established.

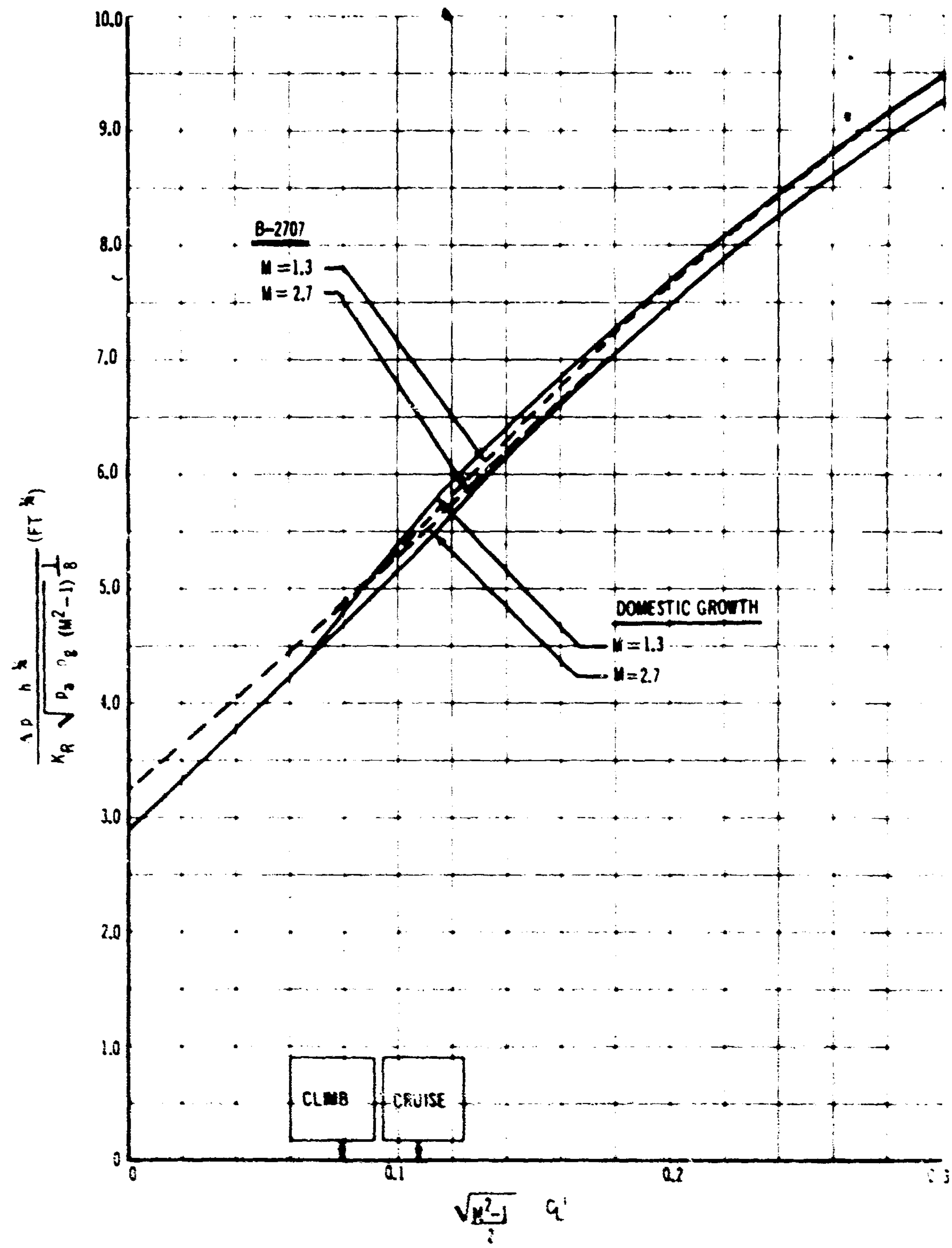


Figure 6-10. Far-Field Sonic Boom Comparison

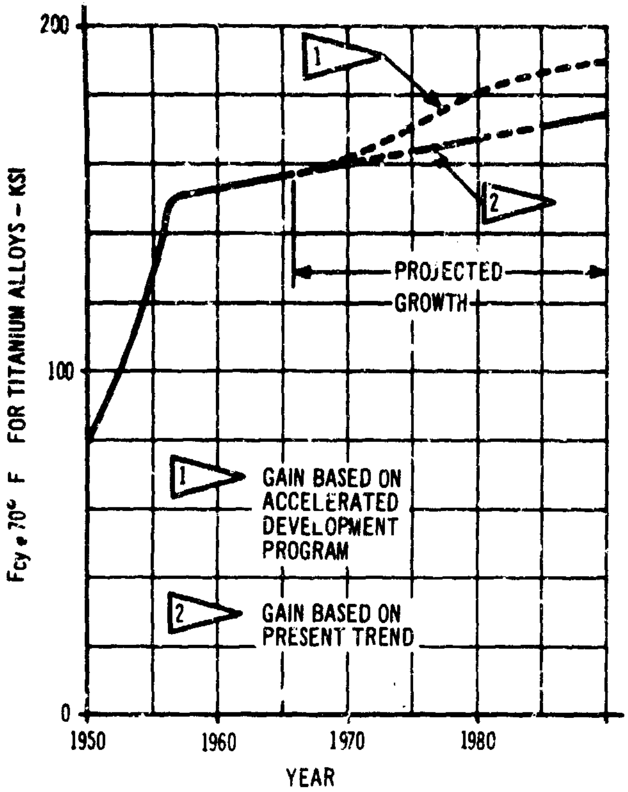


Figure 6–11. Projected Property Growth – Titanium Alloys

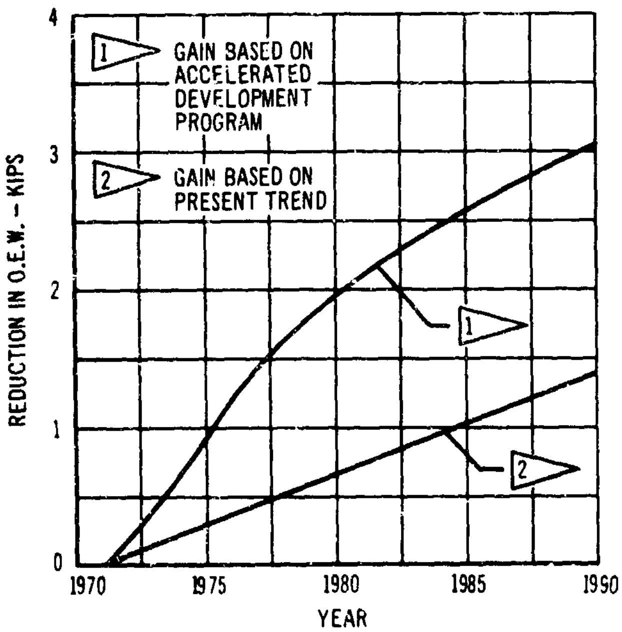


Figure 6–12 Projected Reduction in O.E.W. for Growth Airplanes

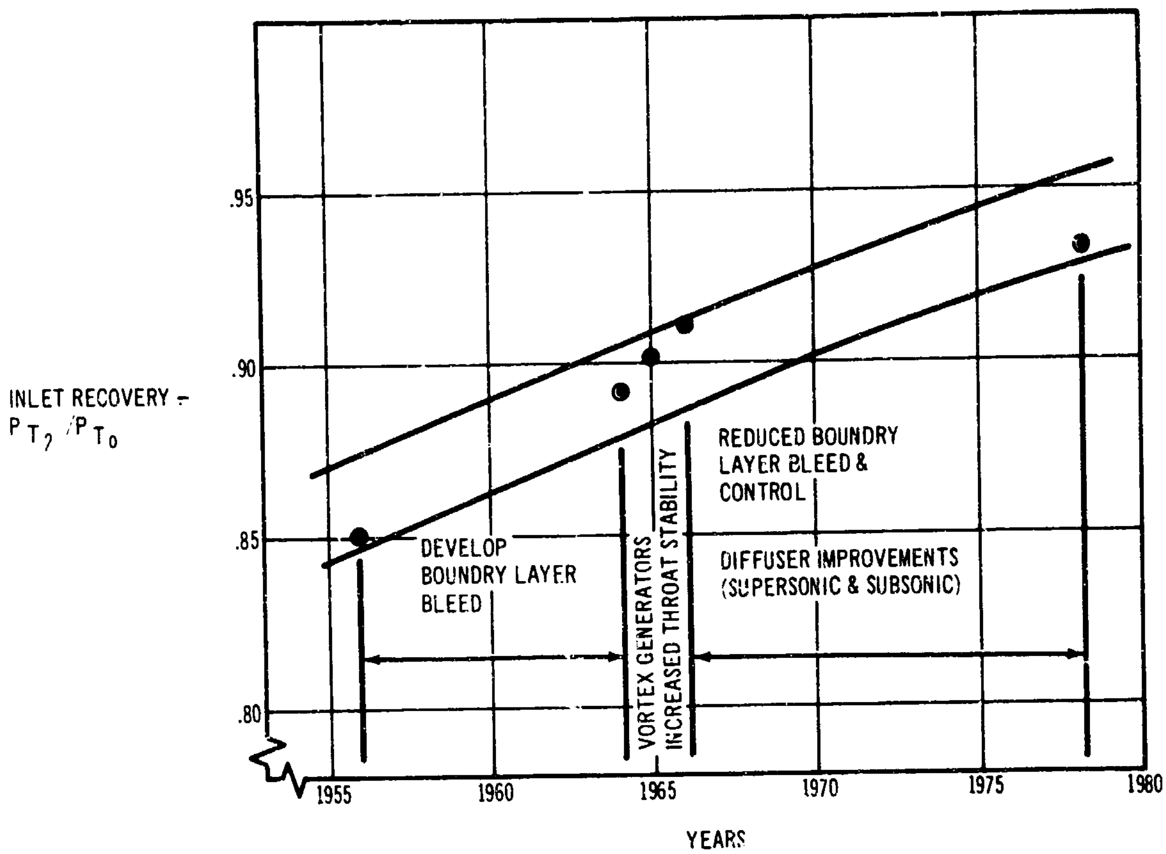


Figure 6-13. Inlet Recovery Growth

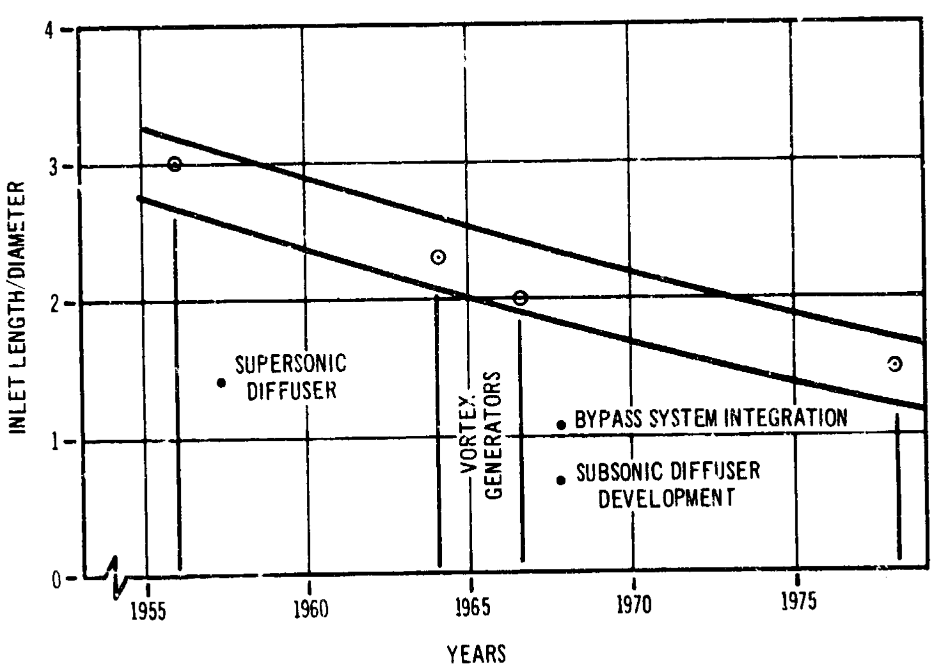


Figure 6-14. Inlet Length/Diameter Growth

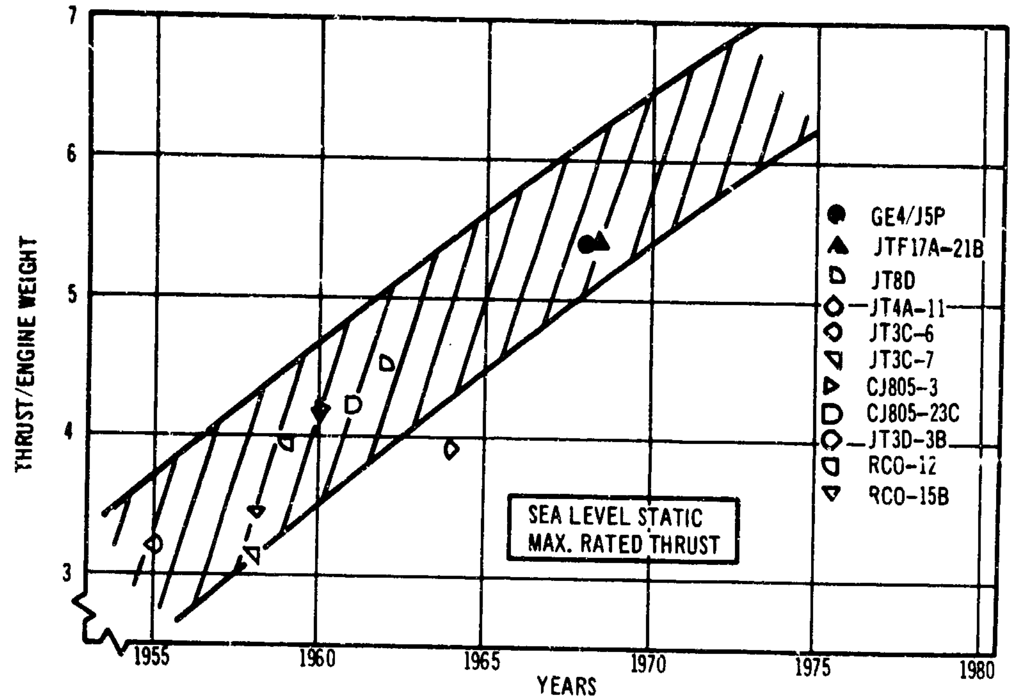


Figure 6-15. Thrust/Weight Ratio Growth

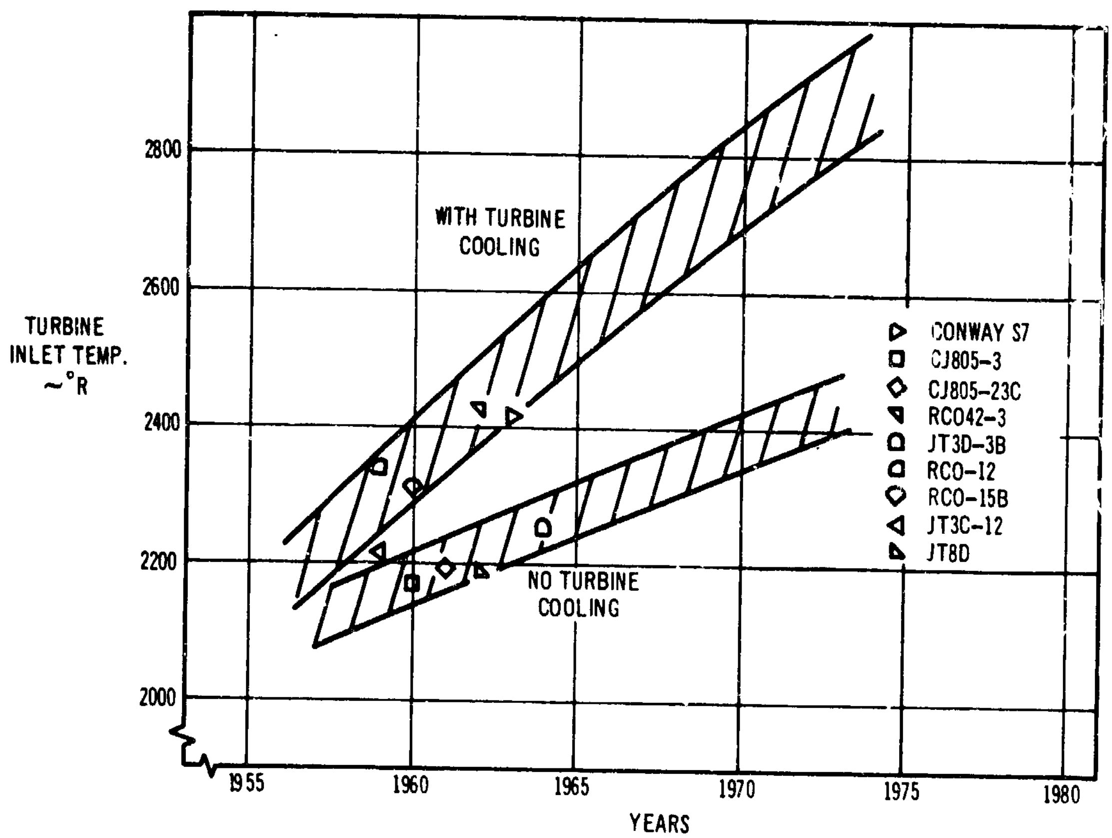


Figure 6-16. Turbine Inlet Temperature Growth

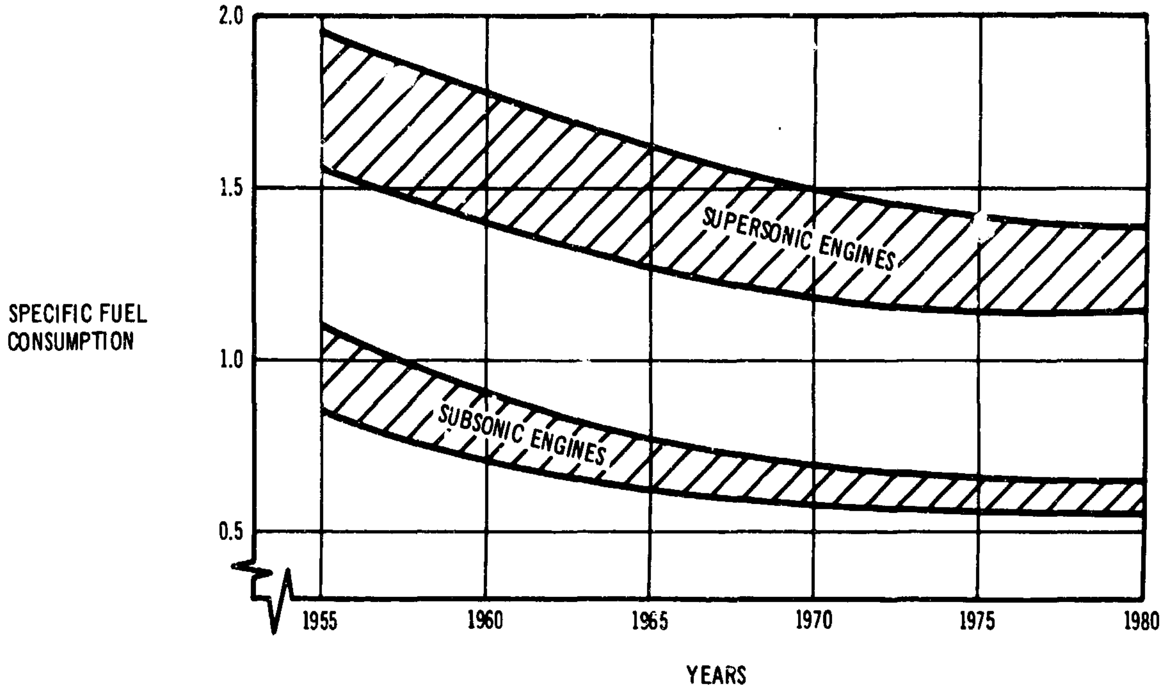


Figure 6–17. SFC Growth

7.0 RECENT CONFIGURATION DEVELOPMENTS

Recognizing the airline acceptance of the very wide Boeing 747 passenger cabin, an optional body design has been developed that provides a wider basic cross section over much of the airplane's length with seven-abreast seating and two aisles in the forward portion of the cabin and five-abreast seating in the aft portion of the cabin (Fig. 7-1). This arrangement is accomplished by widening the body approximately one ft at the wing apex station, and reducing its width a few in. near the aft bulkhead of the cabin. The arrangement is extremely desirable from the standpoint of the passengers because most are not separated from an aisle by more than one seat (Fig. 7-2). Galley and toilet locations are quite flexible. They may be placed either in the middle of the cabin, or arranged along the sidewalls.

This body option accommodates 280 passengers in an international mixed arrangement (10 percent first class - 90 percent tourist), compared with the 277 passenger body specified in the basic portion of the Boeing proposal. The weight and drag of this body, however, are the same as the basic proposal body and all technical data of the basic proposal may be used with either body. If the airlines agree that this wider body is desired, it will be included in both the prototype and production airplanes at no change to the delivery schedules or contract price.

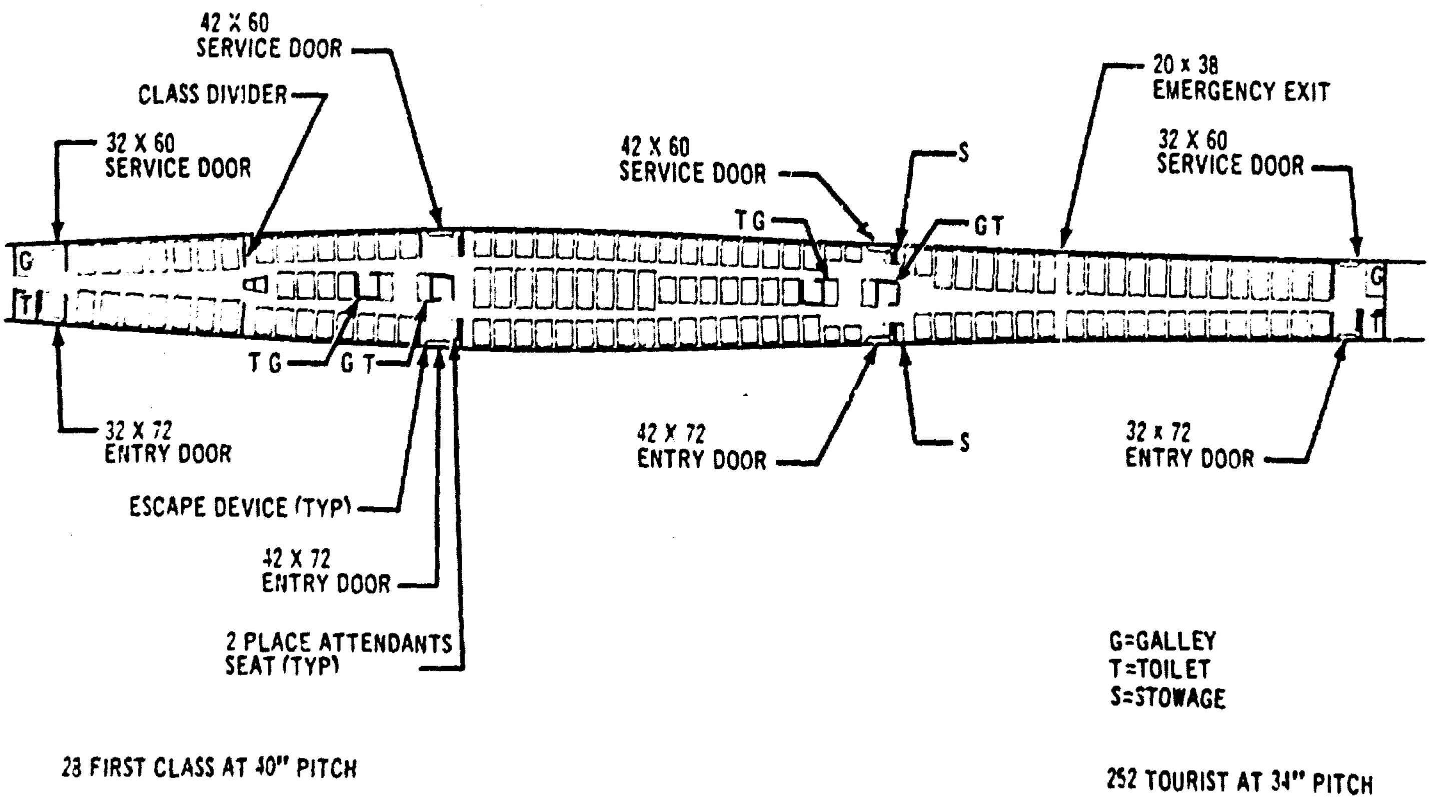


Figure 7-1. 280 Passenger International Mixed Configuration

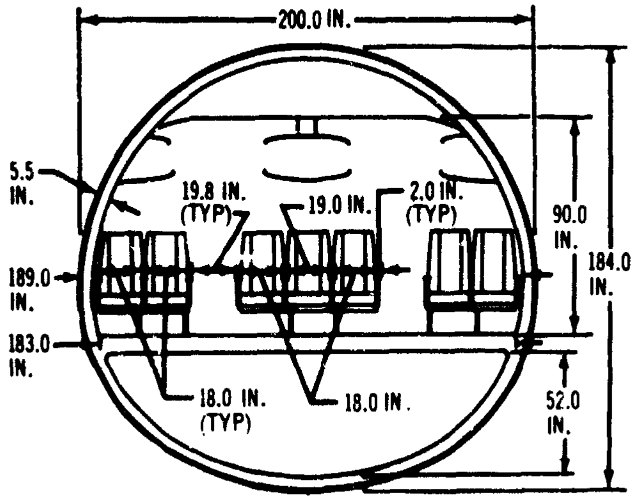
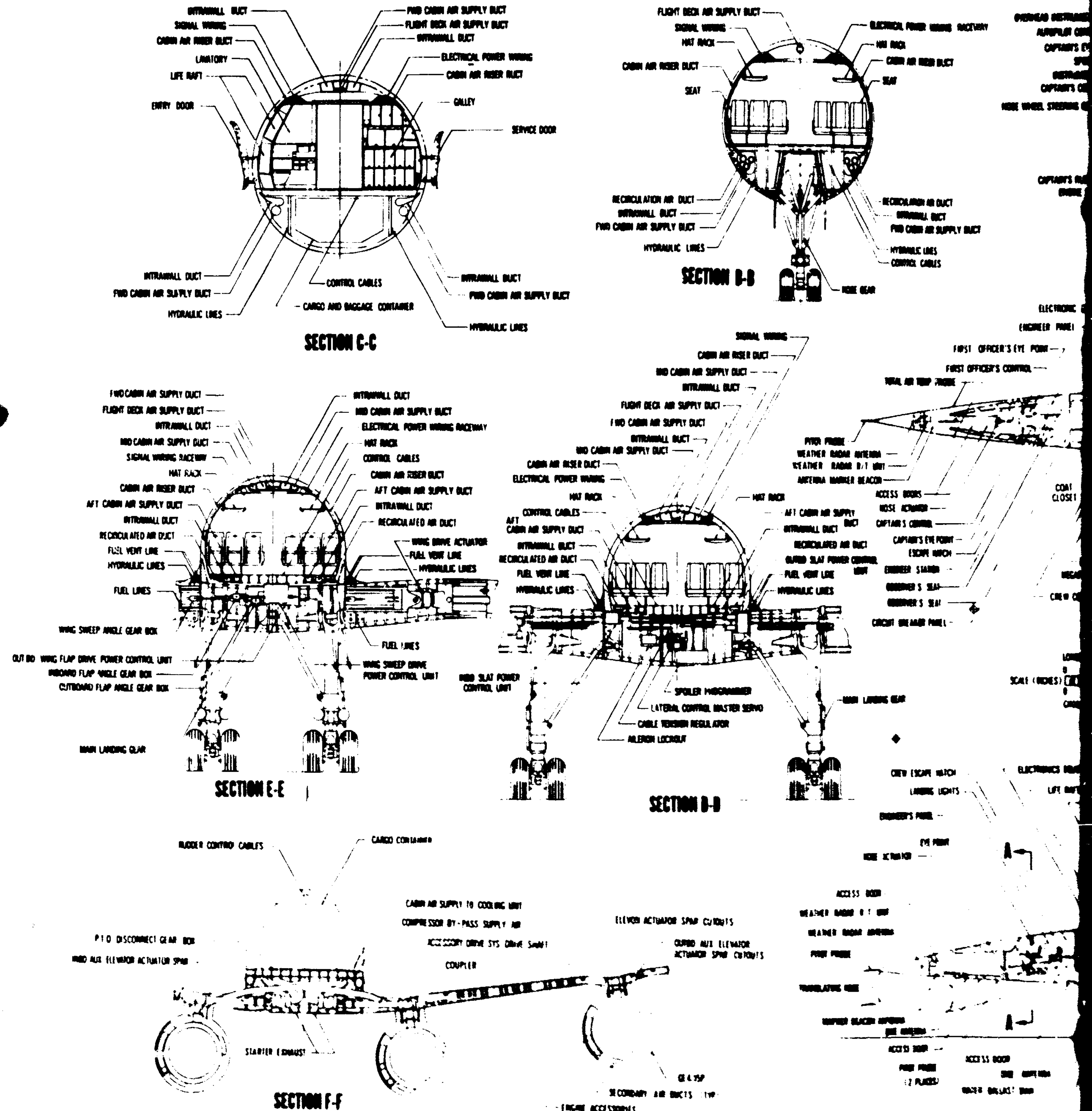


Figure 7-2. Seven Abreast Cross Section

SEE FULL SIZE DRAWING IN POCKET INSIDE BACK COVER



A

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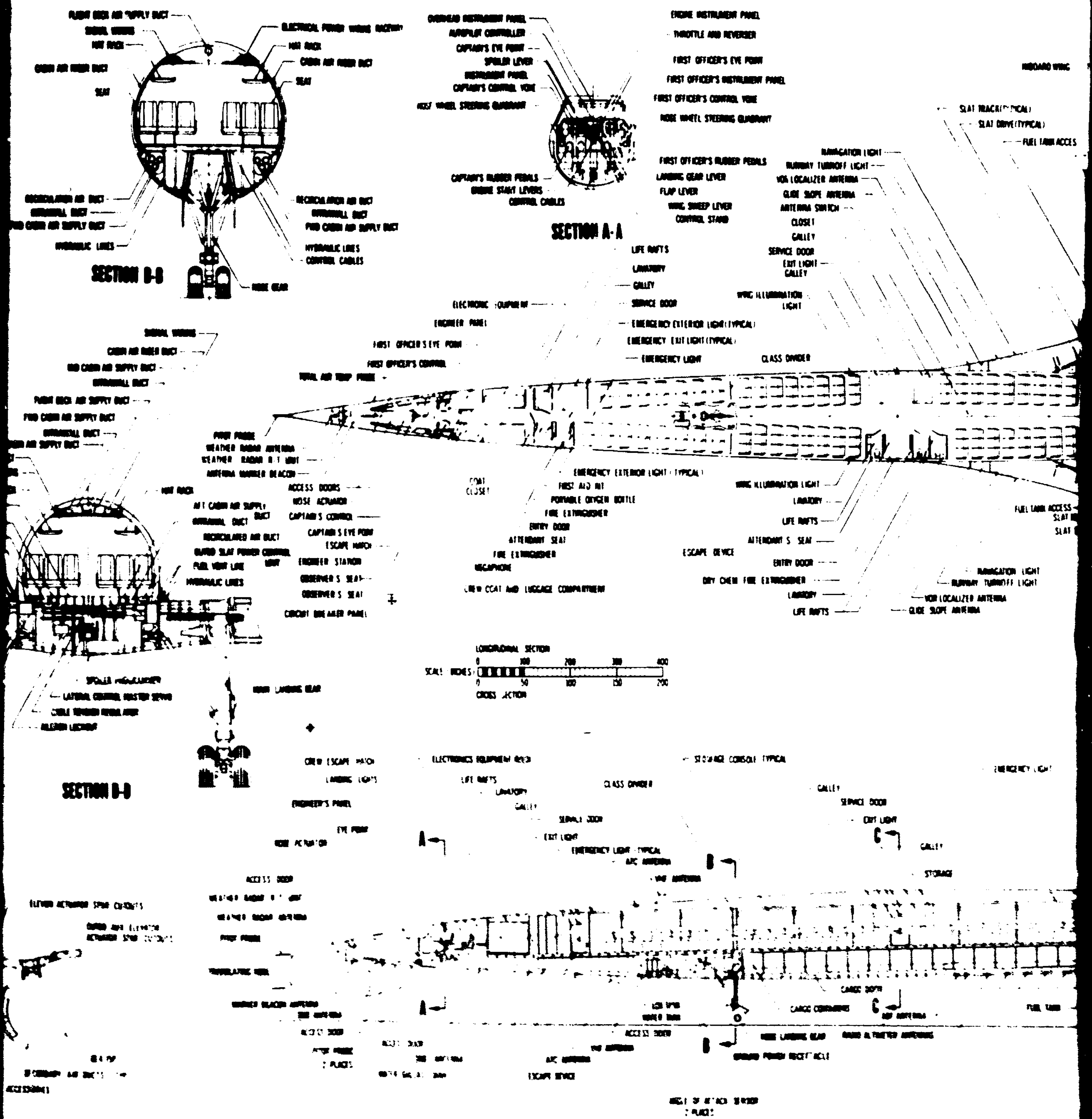
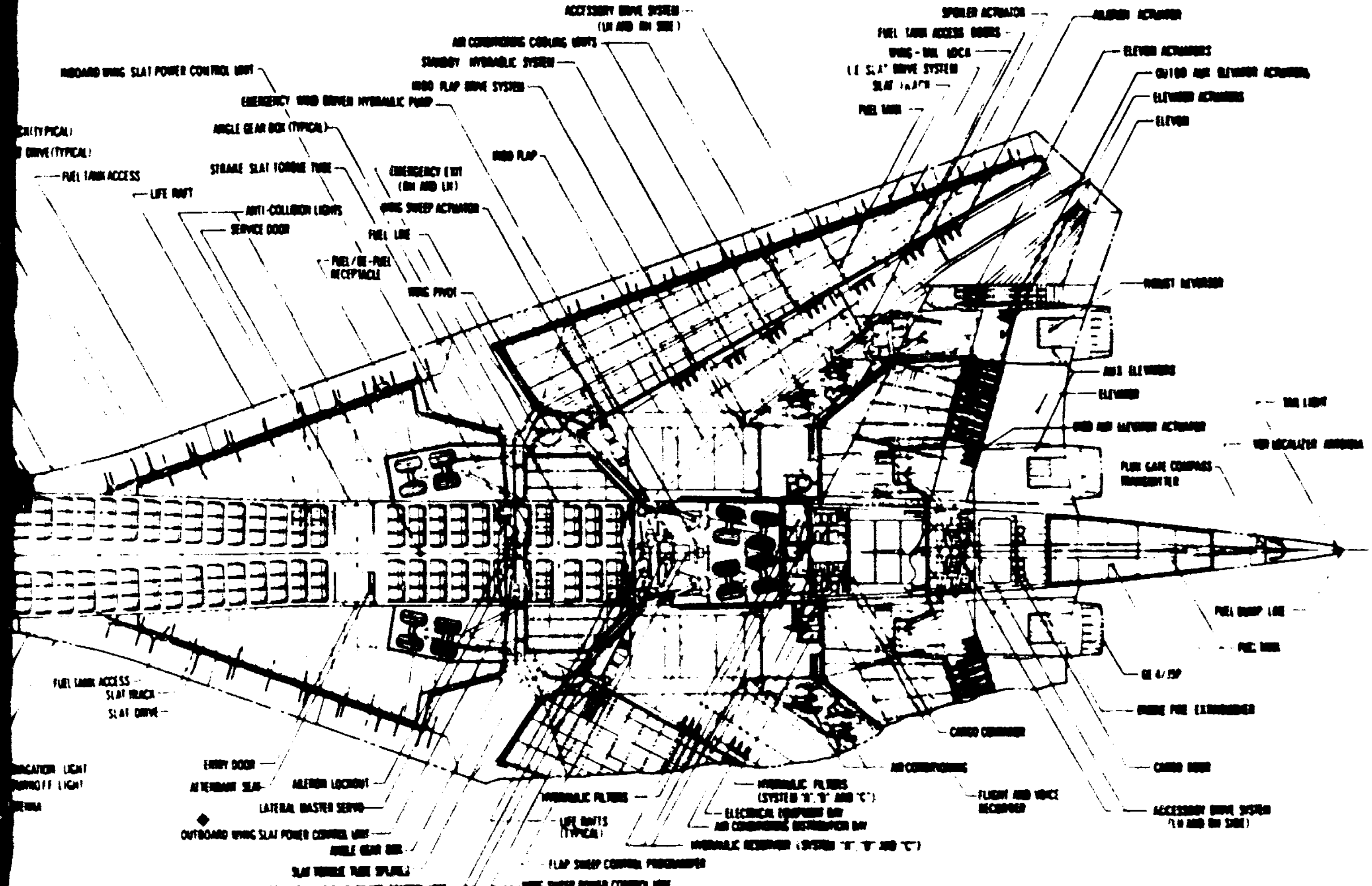

SECTION B-B
SECTION A-A
SECTION D-D
FLIGHT DECK AIR SUPPLY DUCT
SIGNAL WIRING
HAT RACK
CABIN AIR RISER DUCT
SEAT
ELECTRICAL POWER WIRING RACEWAY
RECIRCULATION AIR DUCT
SIDEWALL DUCT
FWD CABIN AIR SUPPLY DUCT
HYDRAULIC LINES
CONTROL CABLES
NOSE GEAR
OVERHEAD INSTRUMENT PANEL
AUTOPILOT CONTROLLER
CAPTAIN'S EYE POINT
SPOILER LEVER
INSTRUMENT PANEL
CAPTAIN'S CONTROL YOKE
NOSE WHEEL STEERING QUADRANT
CAPTAIN'S RUDDER PEDALS
ENGINE START LEVERS
CONTROL CABLES
ENGINE INSTRUMENT PANEL
THROTTLE AND REVERSER
FIRST OFFICER'S EYE POINT
FIRST OFFICER'S INSTRUMENT PANEL
FIRST OFFICER'S CONTROL YOKE
NOSE WHEEL STEERING QUADRANT
FIRST OFFICER'S RUDDER PEDALS
LANDING GEAR LEVER
FLAP LEVER
WING SWEEP LEVER
CONTROL STAND
INBOARD WING
SLAT DRIVE (TYPICAL)
NAVIGATION LIGHT
RUNWAY TURNOFF LIGHT
VOR LOCALIZER ANTENNA
GLIDE SLOPE ANTENNA
ANTENNA SWITCH
CLOSET
GALLEY
SERVICE DOOR
EXIT LIGHT
LIFE RAFTS
LAVATORY
ELECTRONIC EQUIPMENT
ENGINEER PANEL
EMERGENCY EXTERIOR LIGHT (TYPICAL)
EMERGENCY EXIT LIGHT (TYPICAL)
EMERGENCY LIGHT
CLASS DIVIDER
WING ILLUMINATION LIGHT
PITOT PROBE
WEATHER RADAR ANTENNA
ANTENNA MARKER BEACON
ACCESS DOORS
NOSE ACTUATOR
CAPTAIN'S CONTROL
CAPTAIN'S EYE POINT
ESCAPE HATCH
ENGINEER STATION
OBSERVER'S SEAT
CIRCUIT BREAKER PANEL
COAT CLOSET
FIRST AID KIT
PORTABLE OXYGEN BOTTLE
FIRE EXTINGUISHER
ENTRY DOOR
ATTENDANT SEAT
MEGAPHONE
CREW COAT AND LUGGAGE COMPARTMENT
ESCAPE DEVICE
DRY CHEM FIRE EXTINGUISHER
FUEL TANK ACCESS
HAT RACK
AFT CABIN AIR SUPPLY DUCT
RECIRCULATED AIR DUCT
FUEL VENT LINE
SPOILER ACTUATOR
LATERAL CONTROL MASTER SERVO
MAIN LANDING GEAR
LONGITUDINAL SECTION
SCALE (INCHES)
0
100
200
300
400
50
150
CROSS SECTION
CREW ESCAPE HATCH
LANDING LIGHTS
ELECTRONICS EQUIPMENT RACK
STORAGE CONSOLE TYPICAL
ENGINEER'S PANEL
EYE POINT
NOSE ACTUATOR
SERVICE DOOR
EXIT LIGHT
EMERGENCY LIGHT TYPICAL
ATC ANTENNA
VHF ANTENNA
STORAGE
A
B
C
ACCESS DOOR
WEATHER RADAR ANTENNA
PITOT PROBE
TRANSLATING NOSE
MARKER BEACON ANTENNA
DME ANTENNA
CARGO DOOR
CARGO COMPARTMENT
ADF ANTENNA
FUEL TANK
MAIN LANDING GEAR
RADIO ALTIMETER ANTENNAS
GROUND POWER RECEPTACLE
2 PLACES
ESCAPE DEVICE
ANGLE OF ATTACK SENSOR
2 PLACES
ACCESSORIES

B



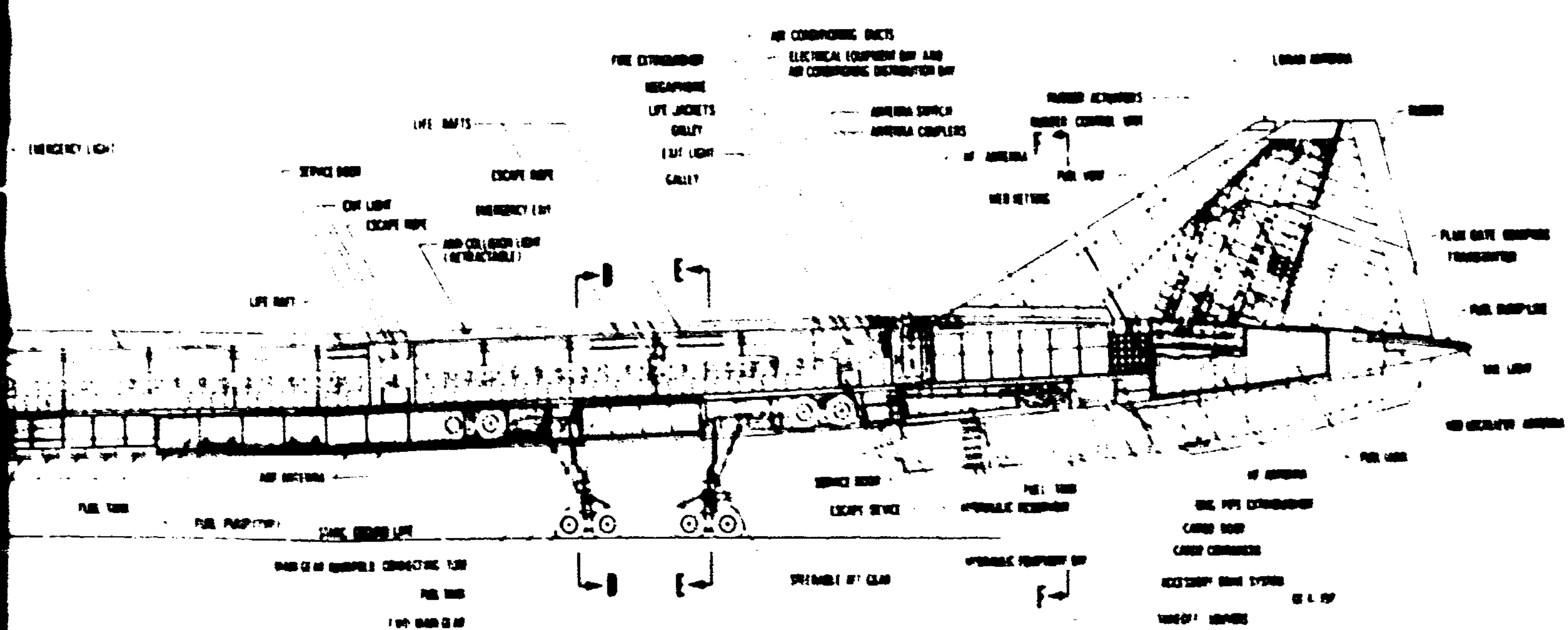
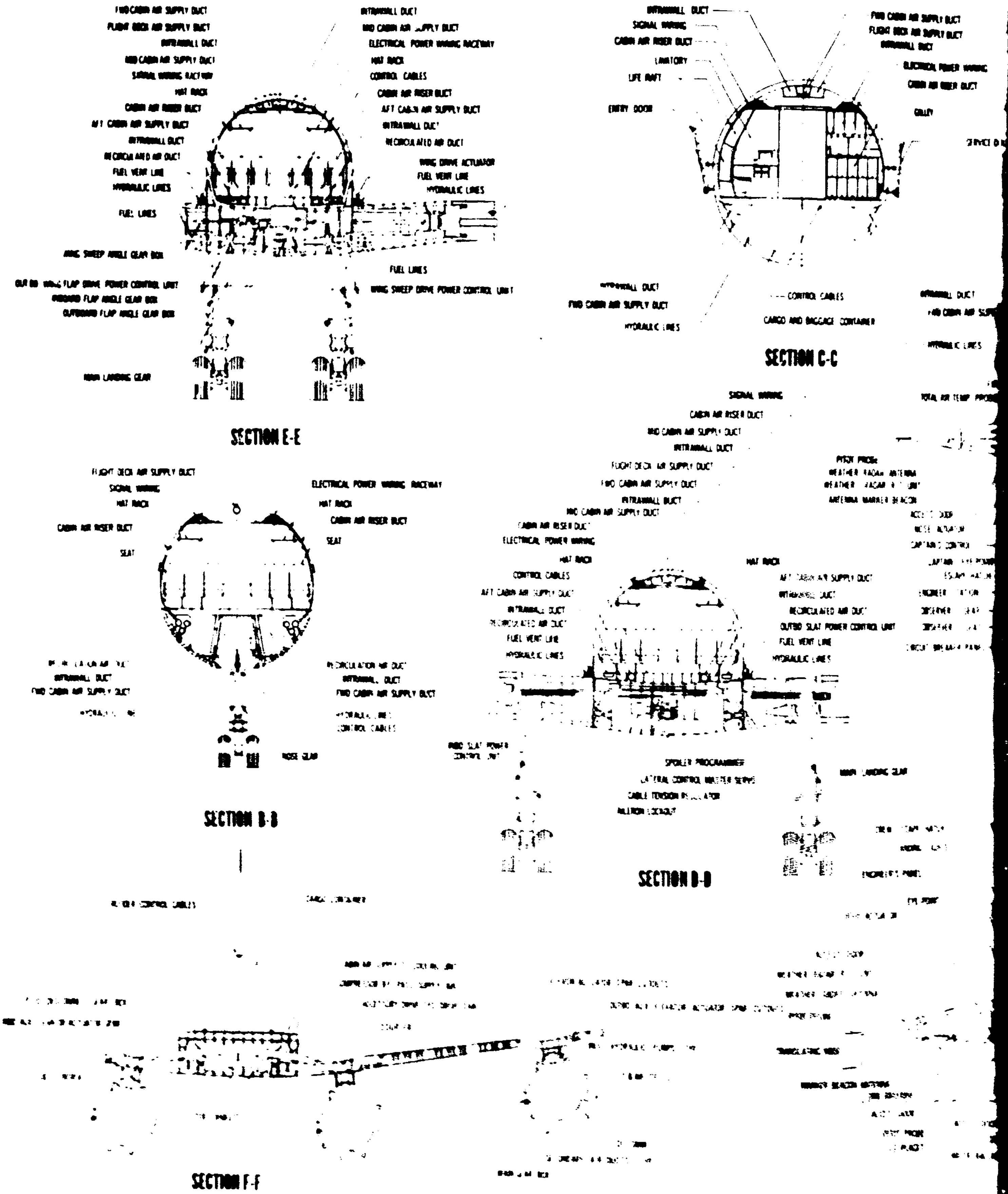


Figure 3-3. Inboard Profile (GE)

SEE FULL SIZE DRAWING IN POCKET INSIDE BACK COVER



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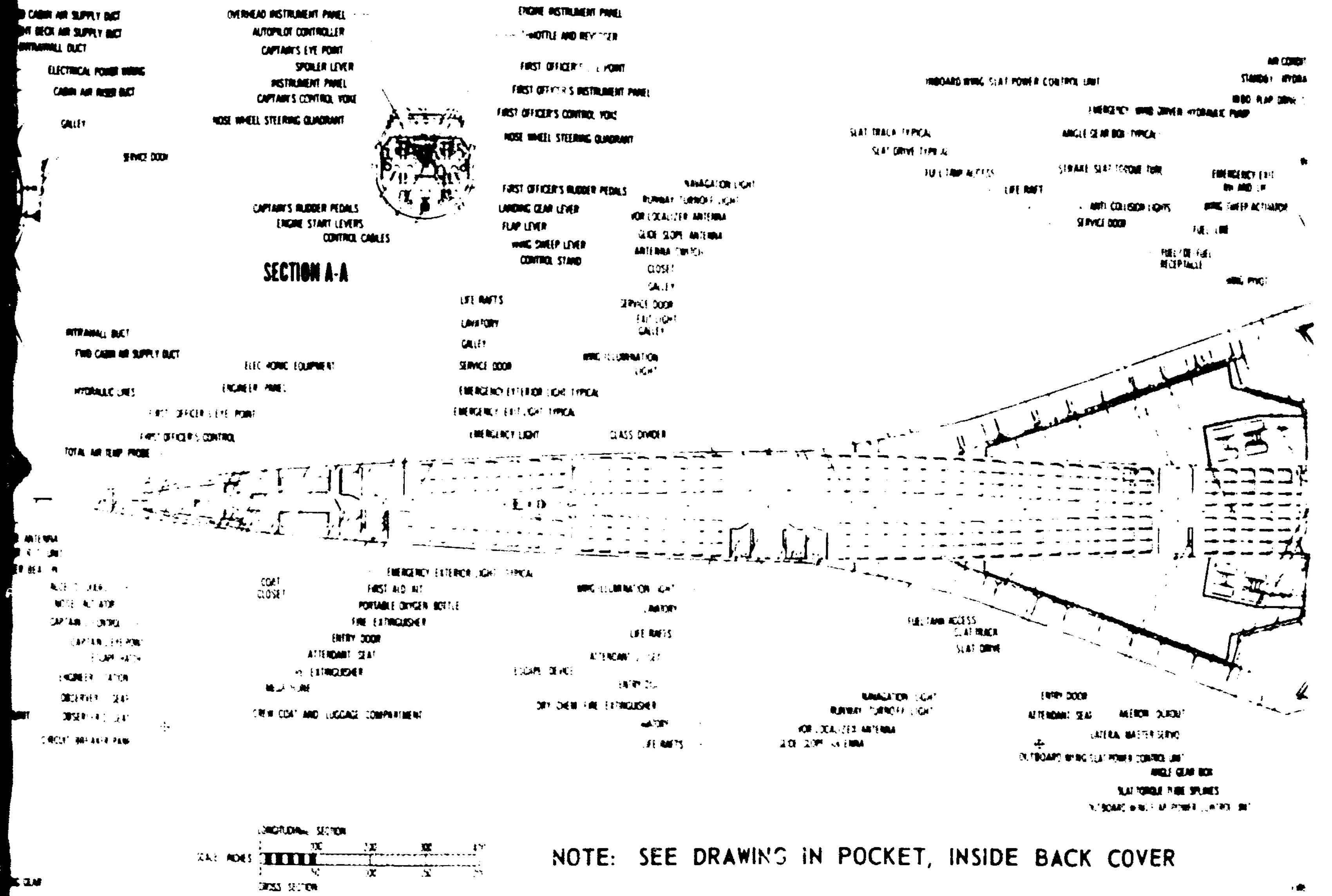

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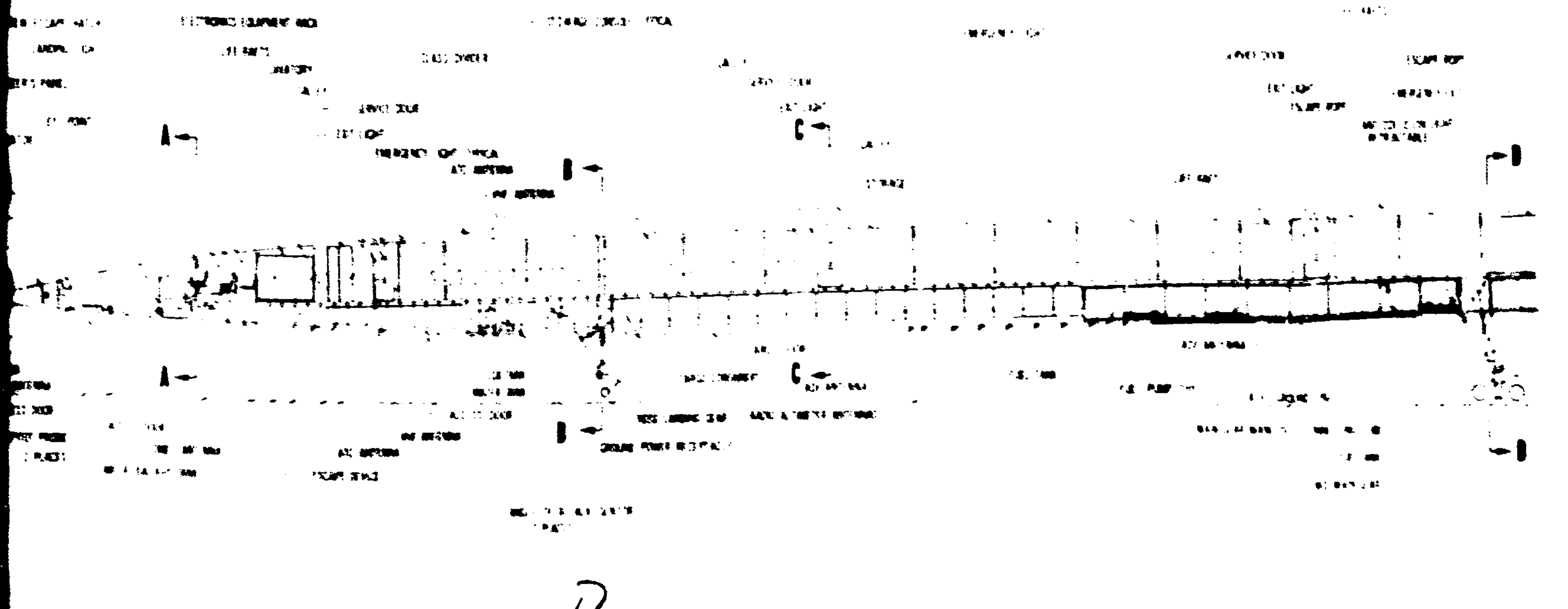

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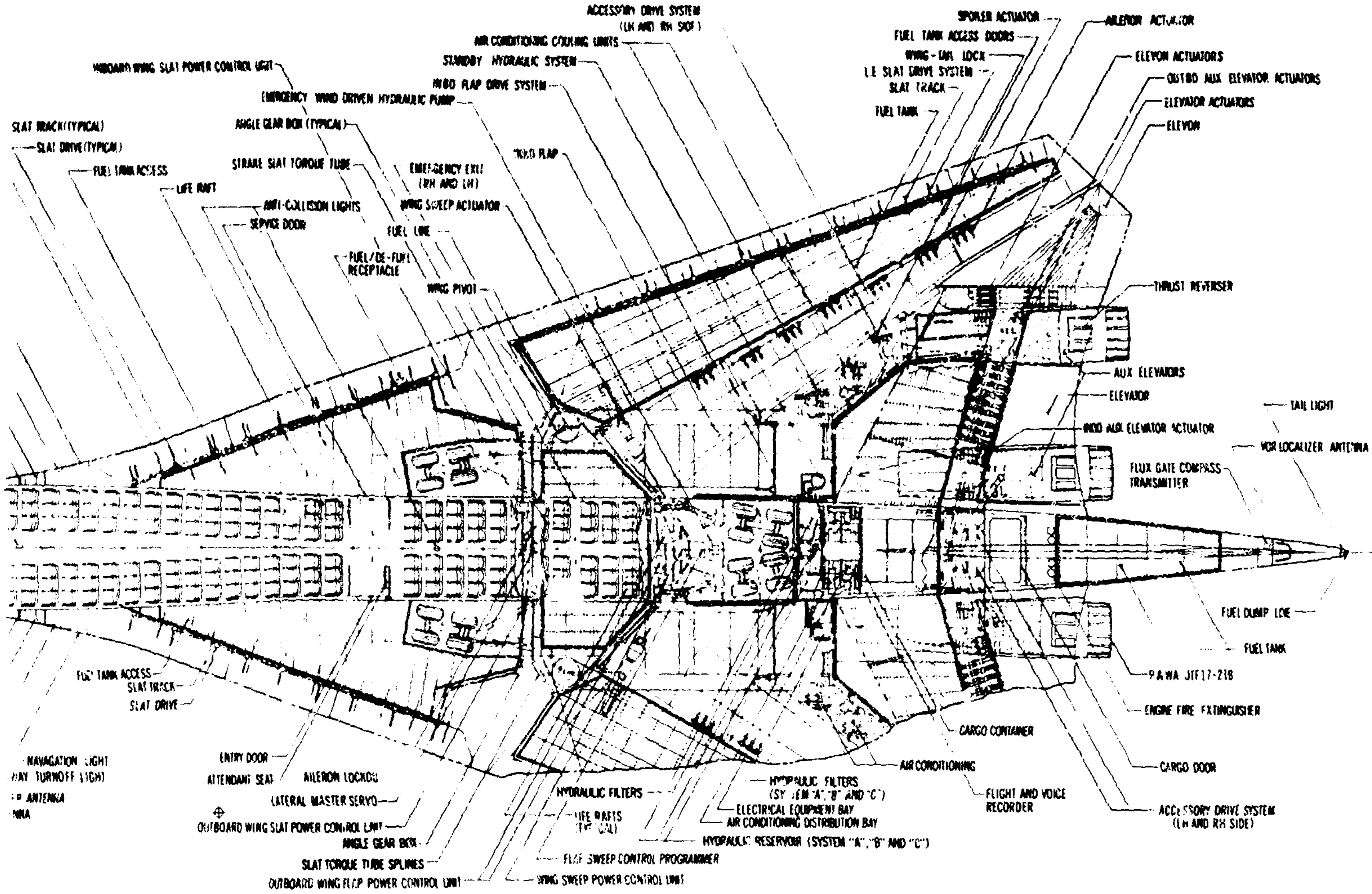

POCKET, INSIDE BACK COVER

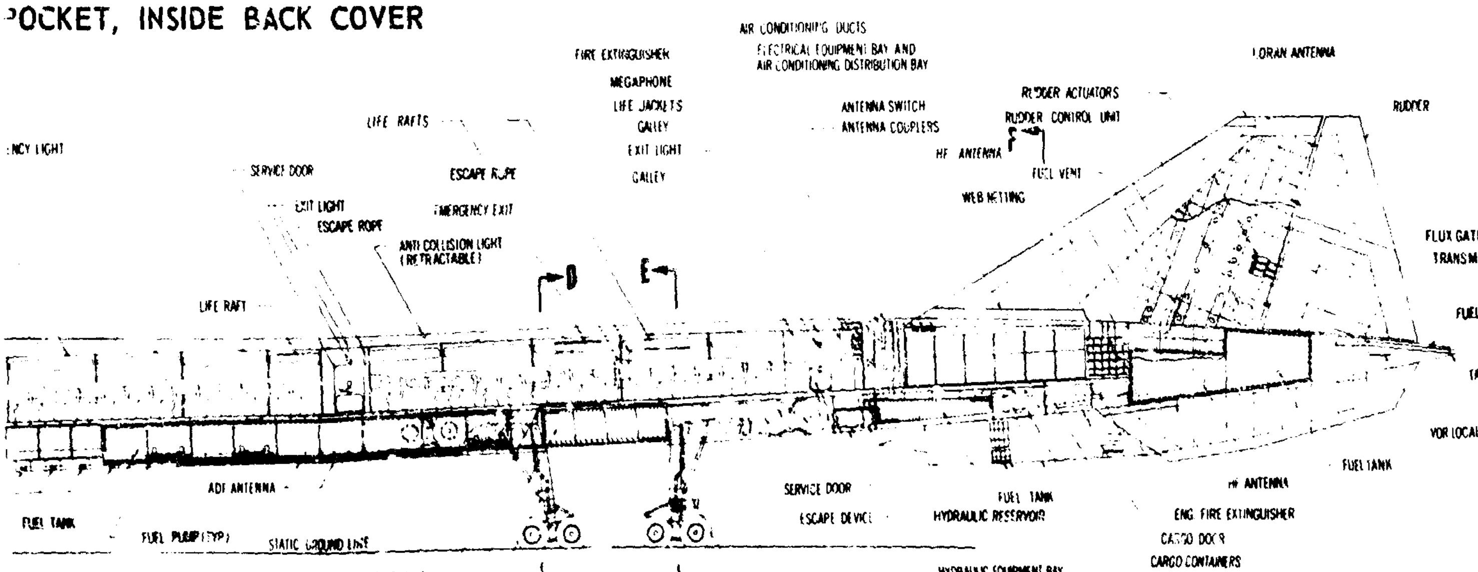

Figure 3–4. Inboard Profile (P&WA)

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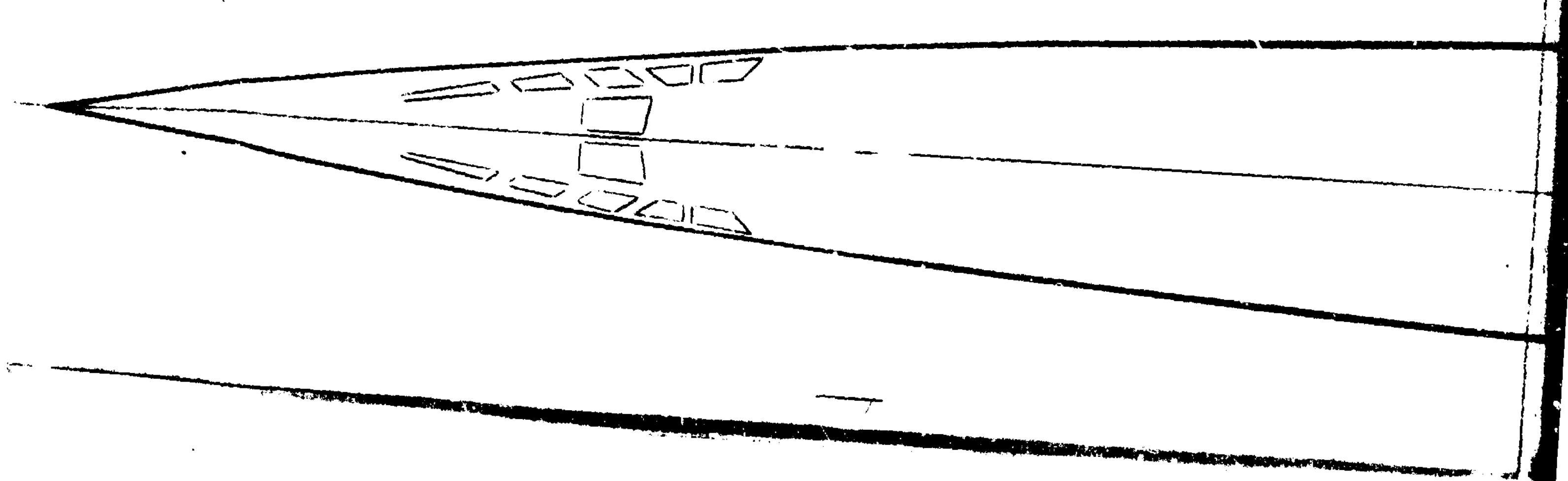

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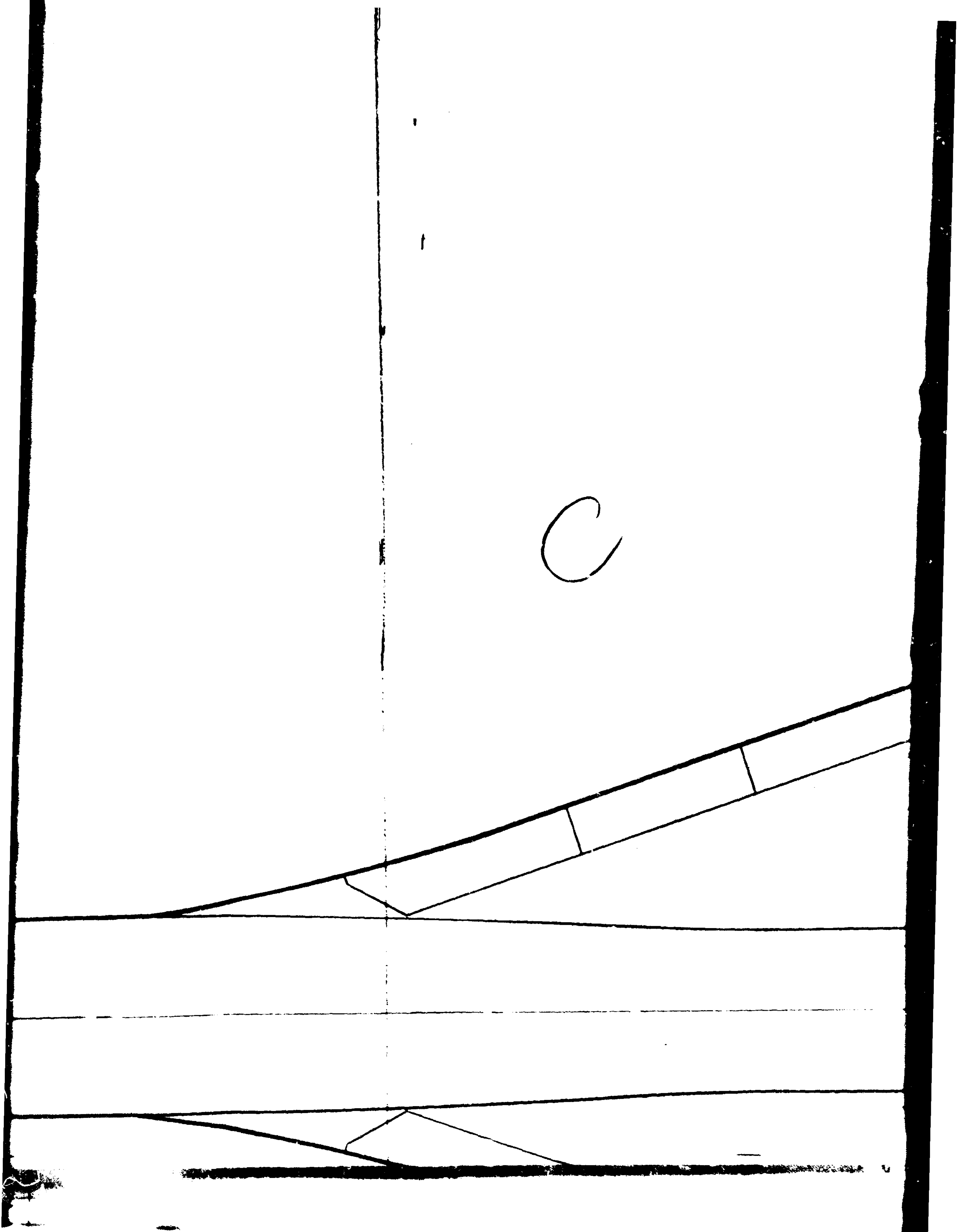
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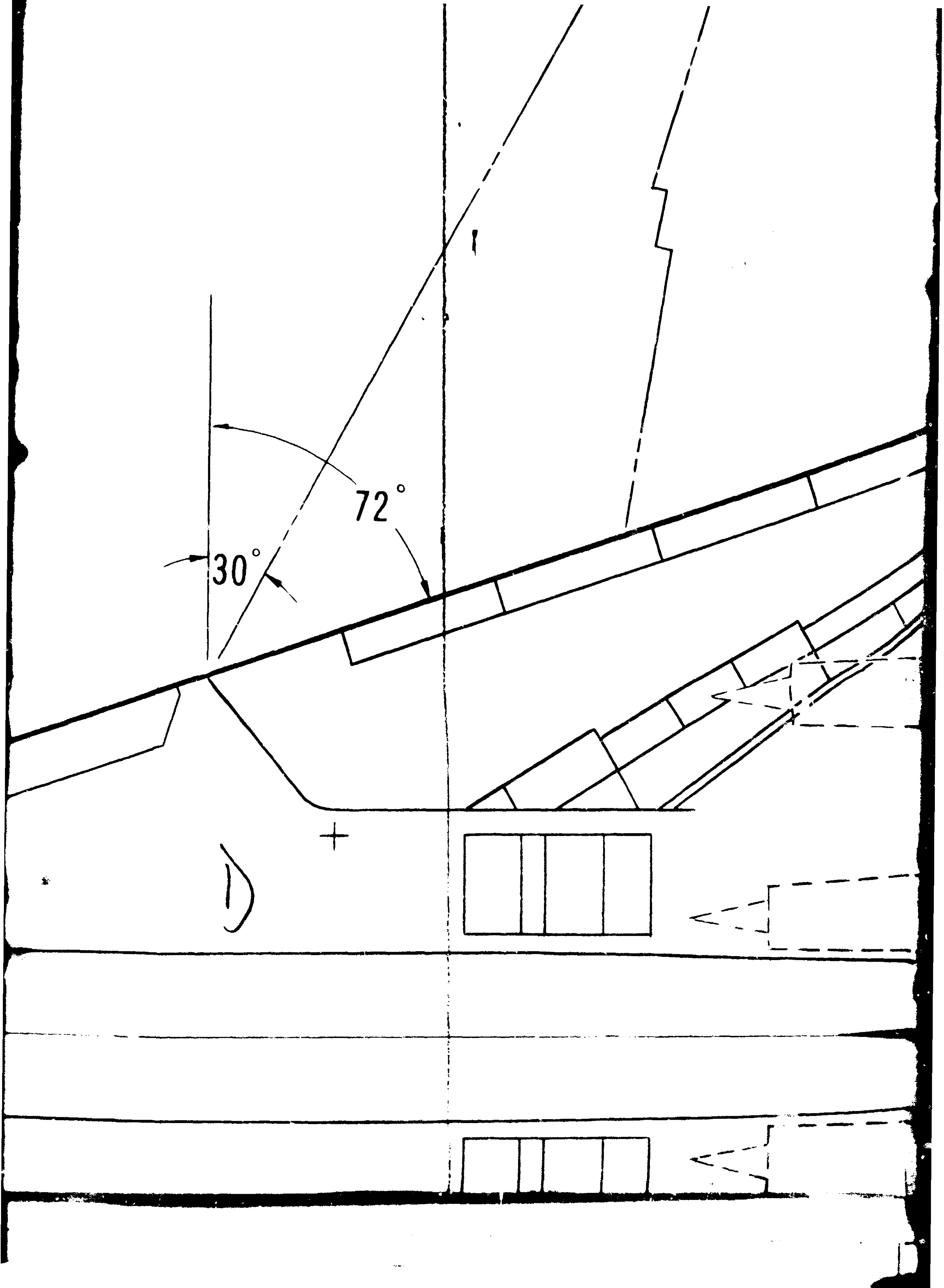
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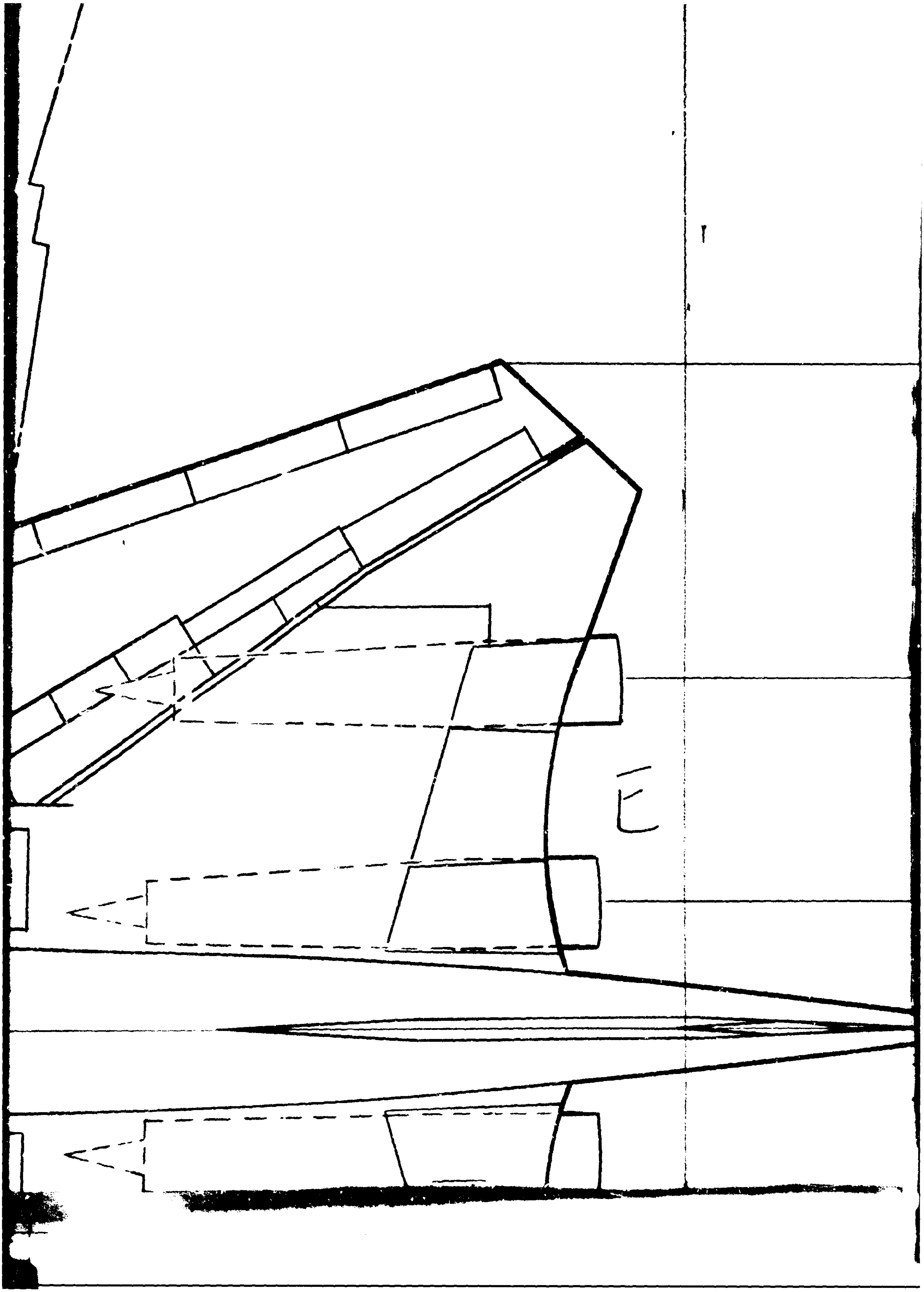
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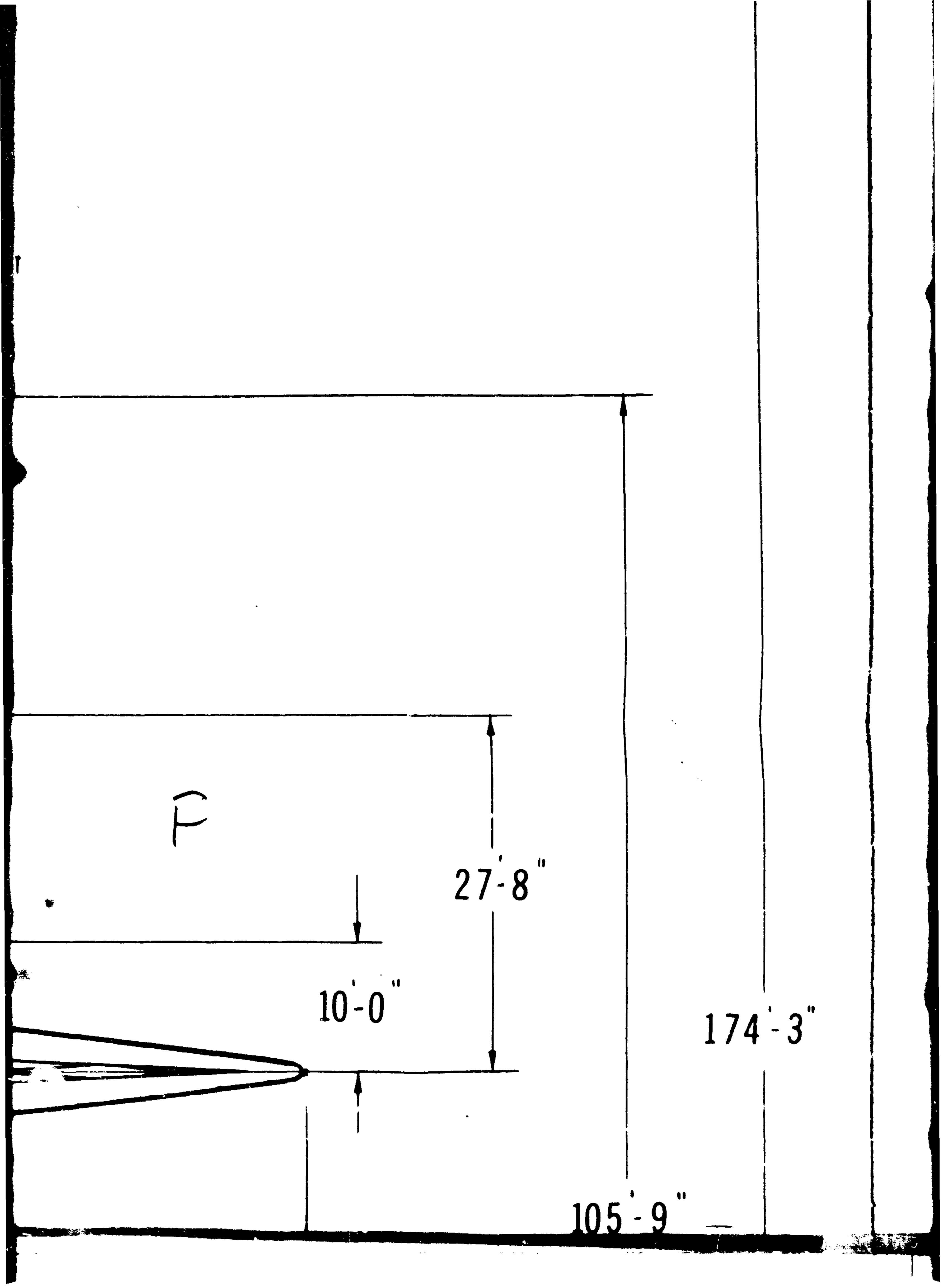
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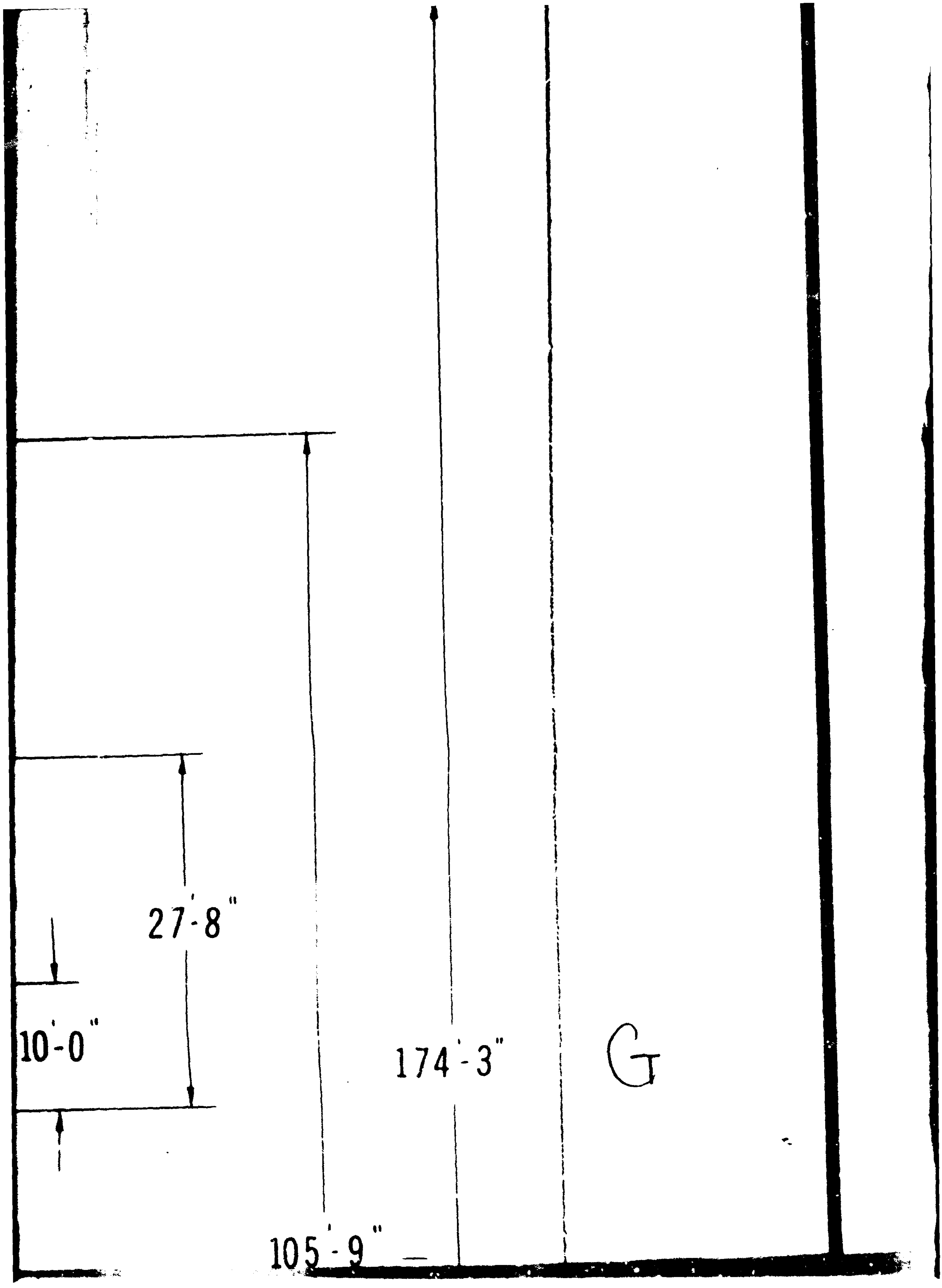
10'-0"
174'-3"
105'-9"


27'-8"
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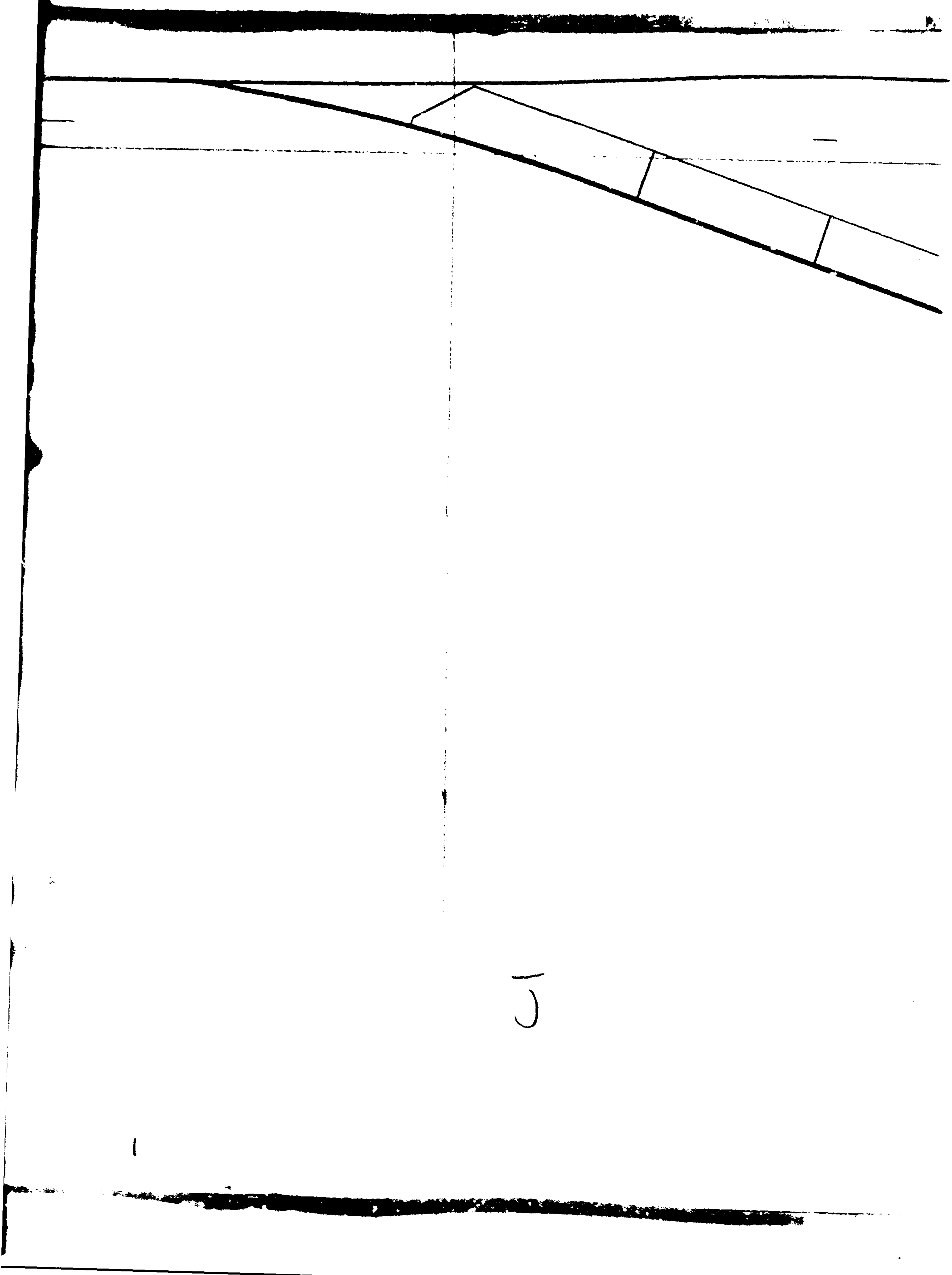

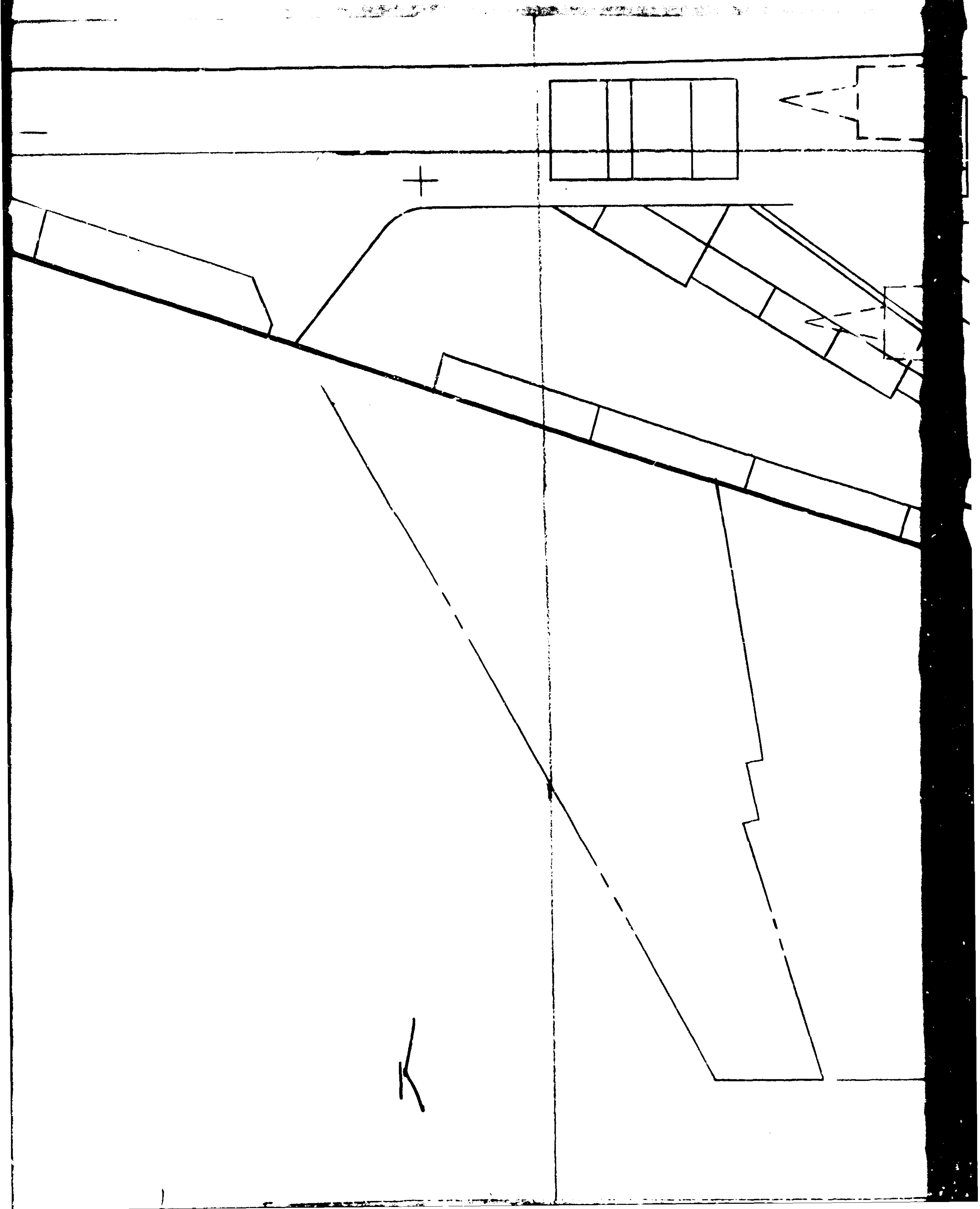

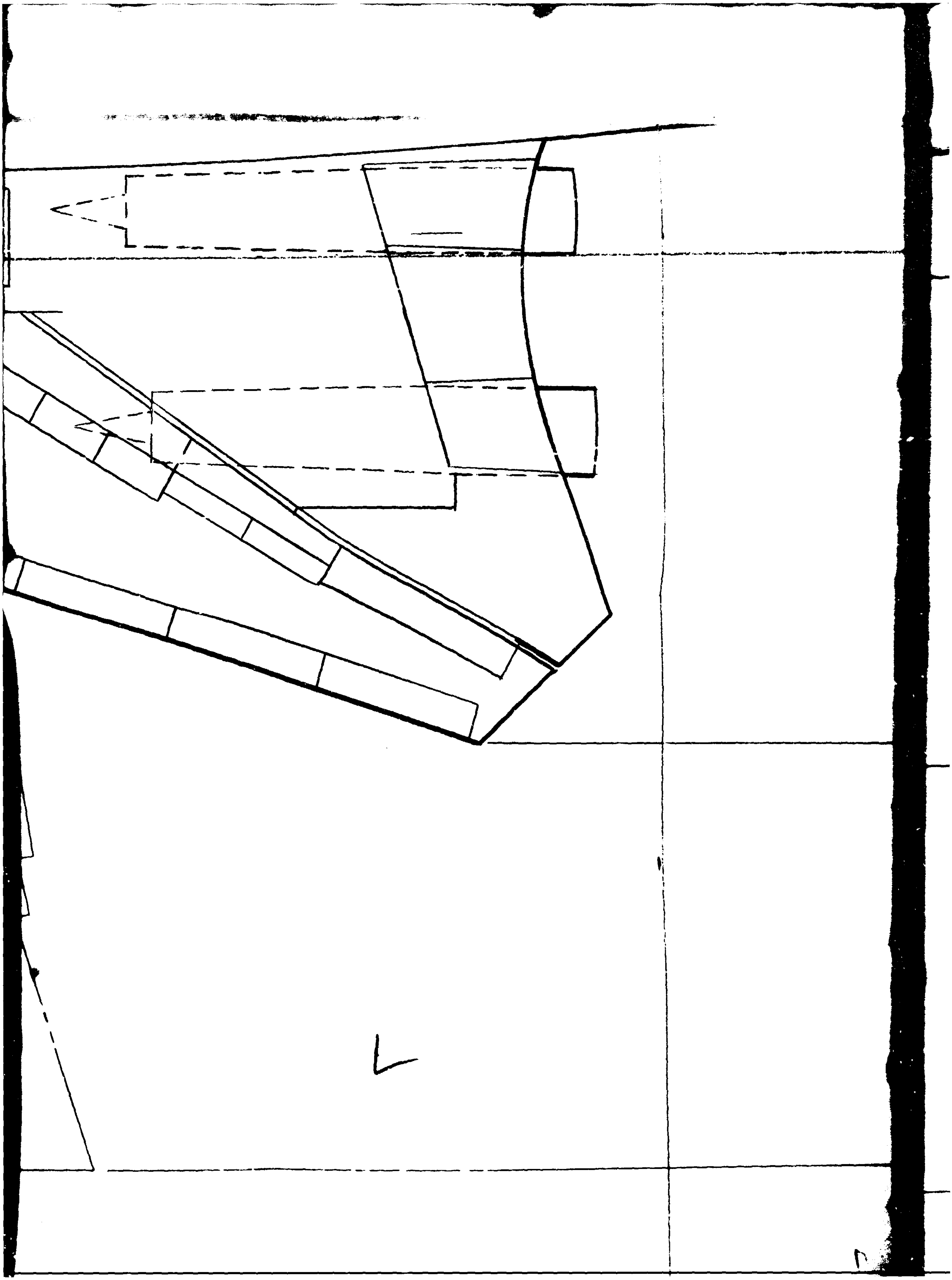

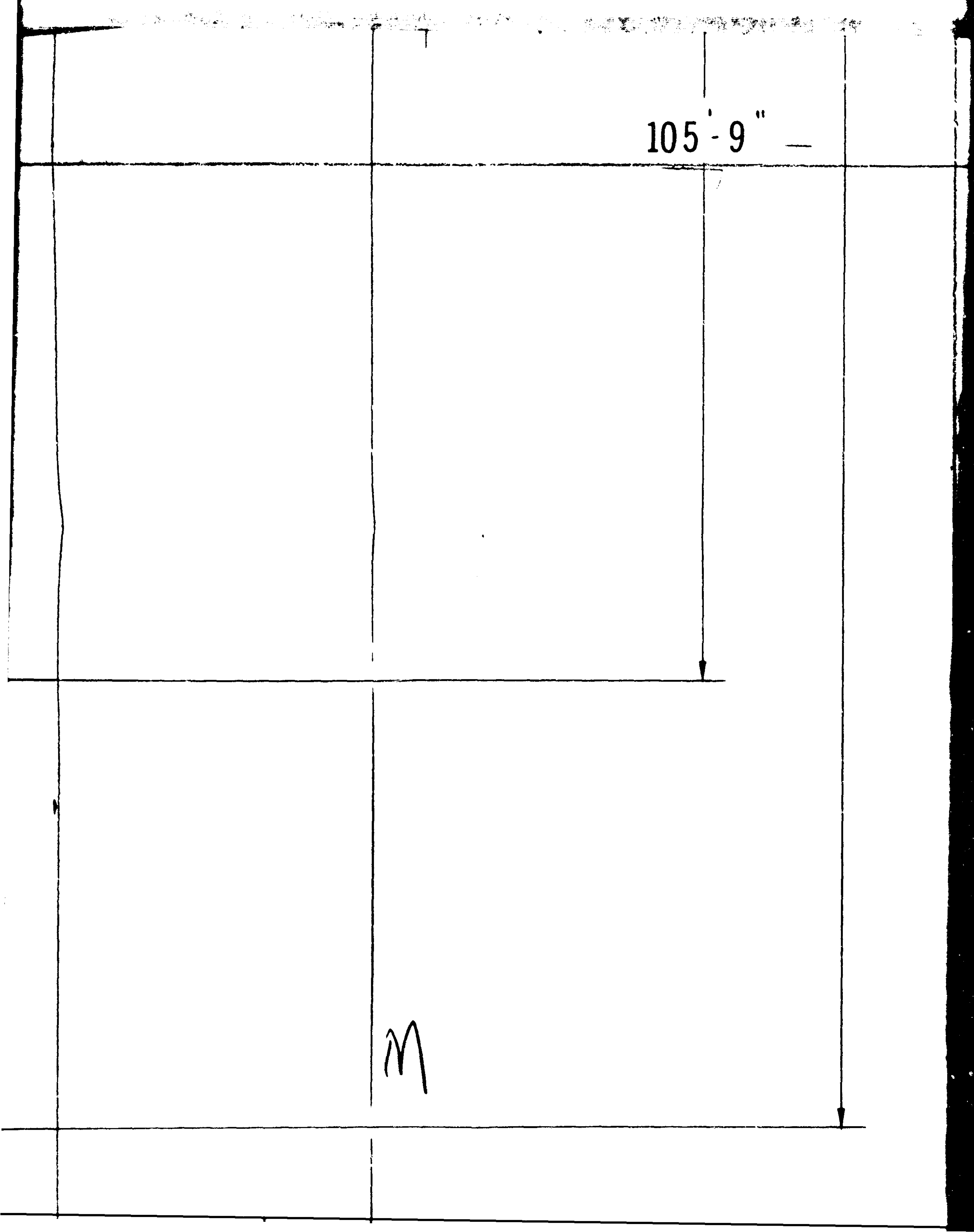
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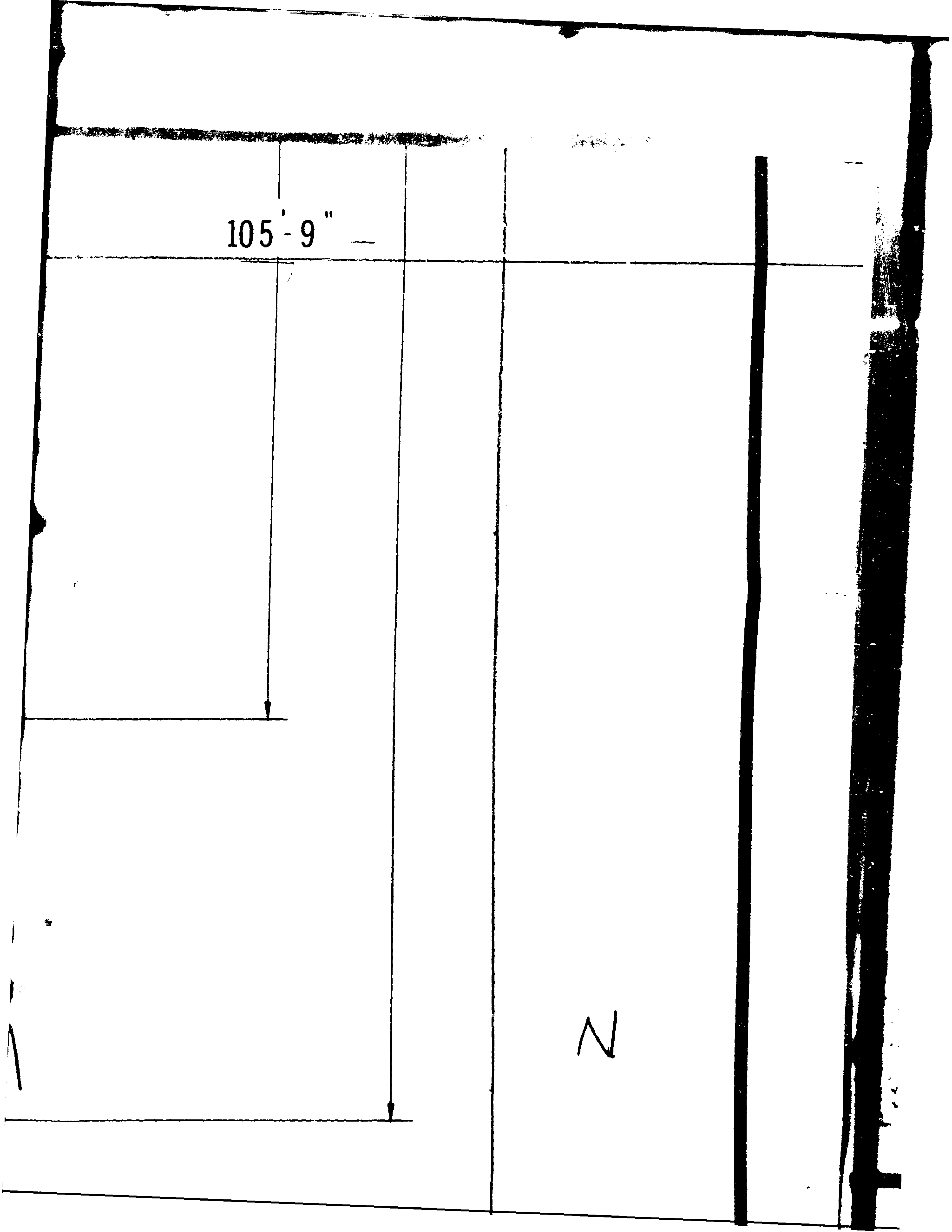
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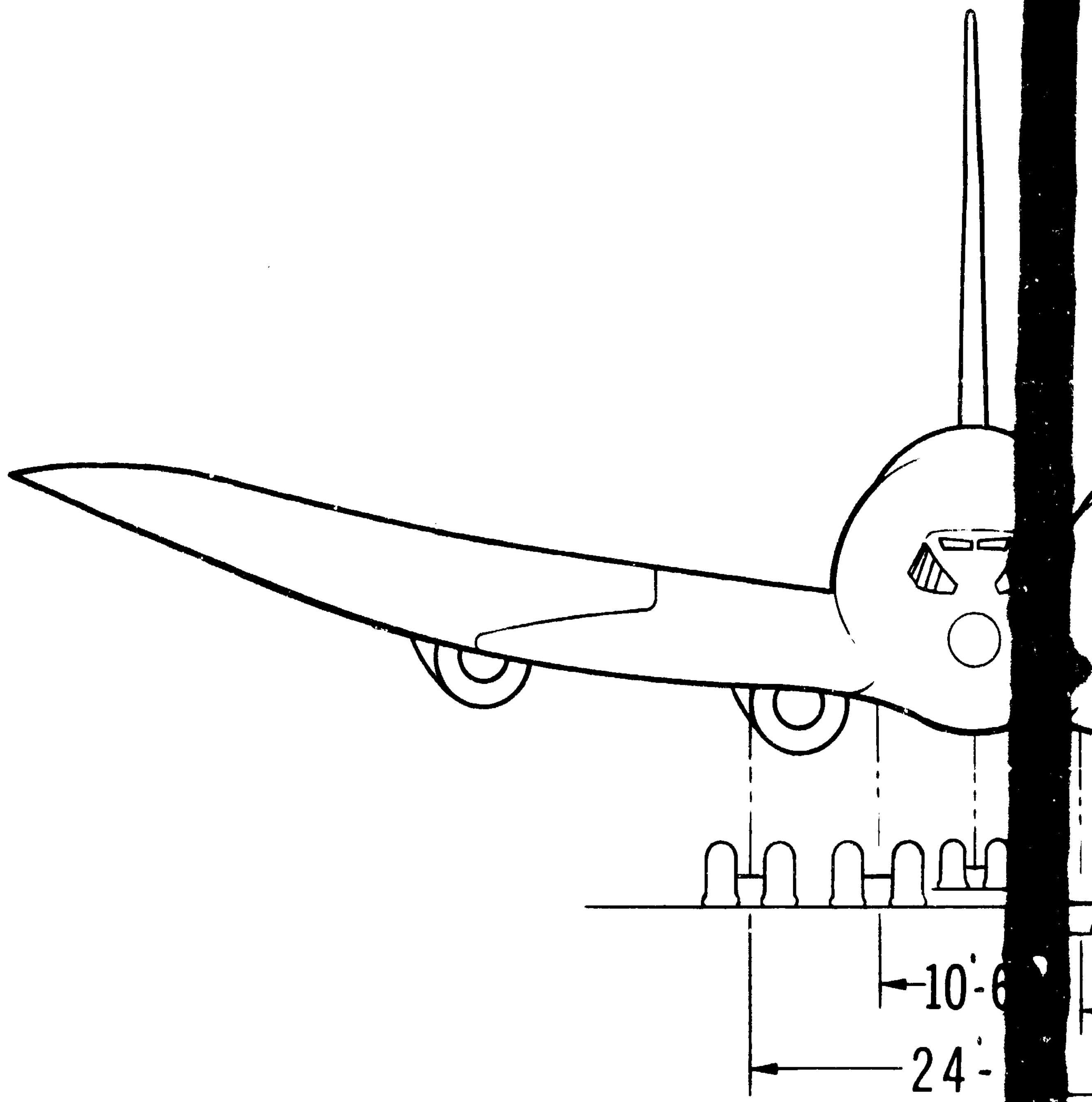
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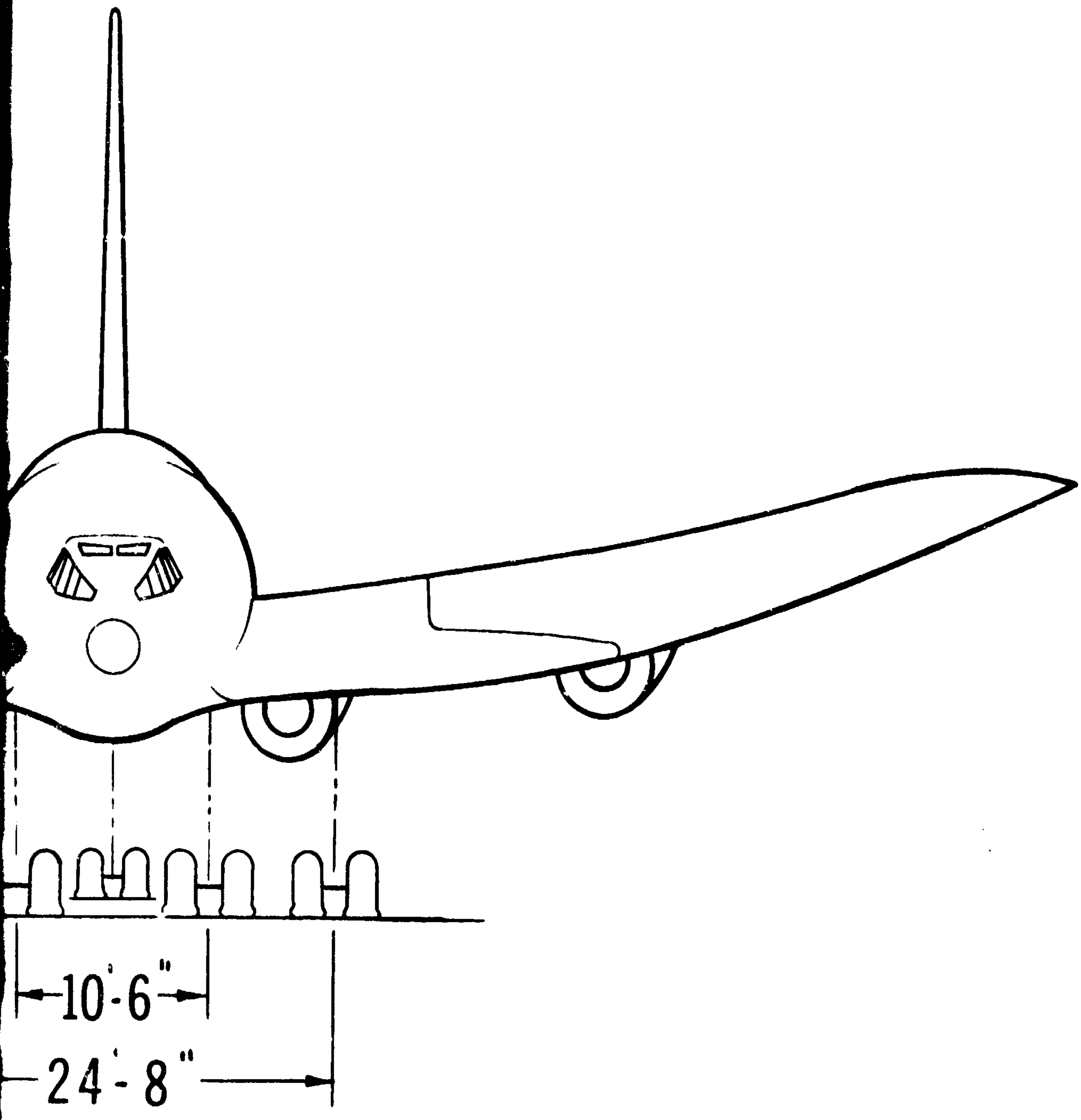

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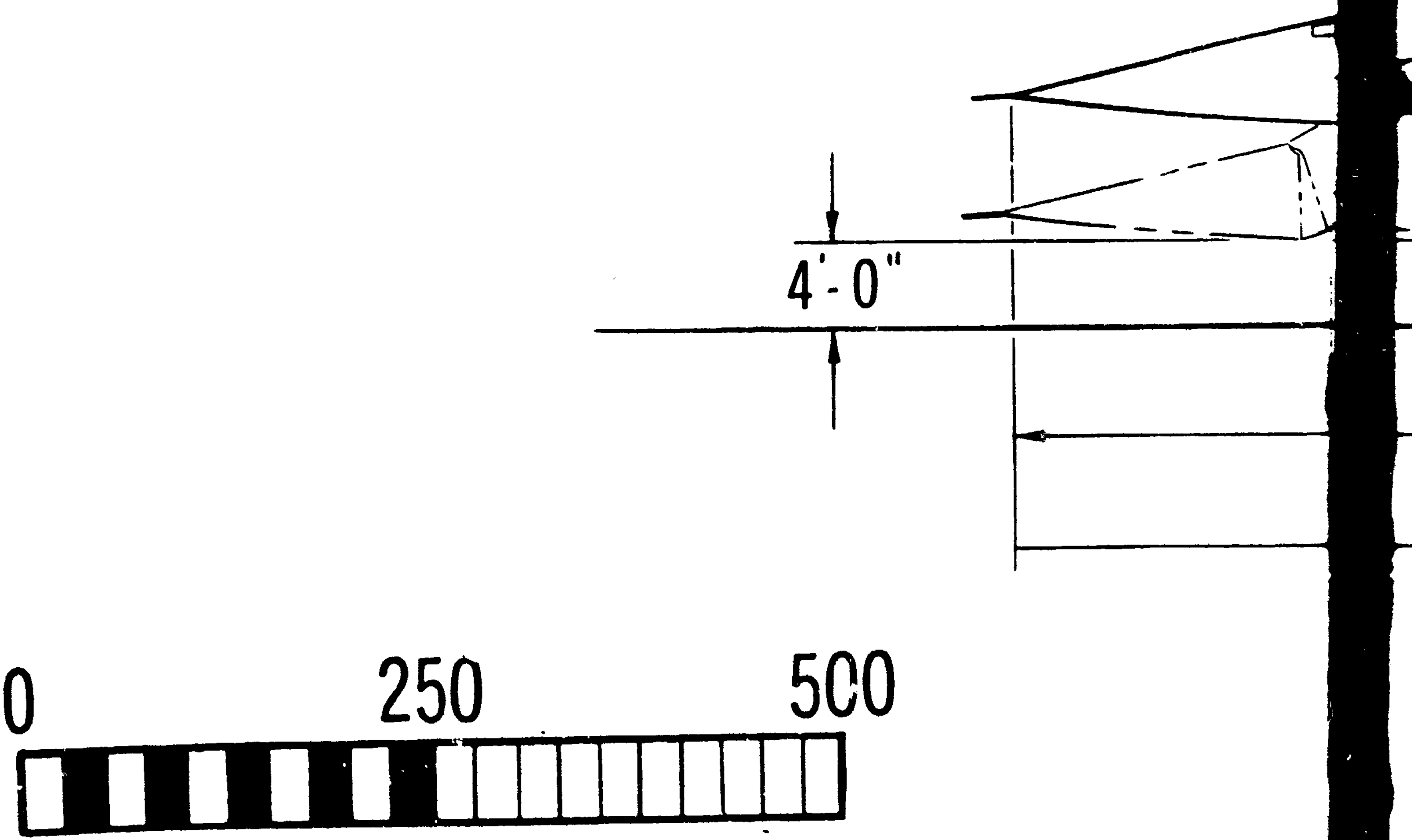

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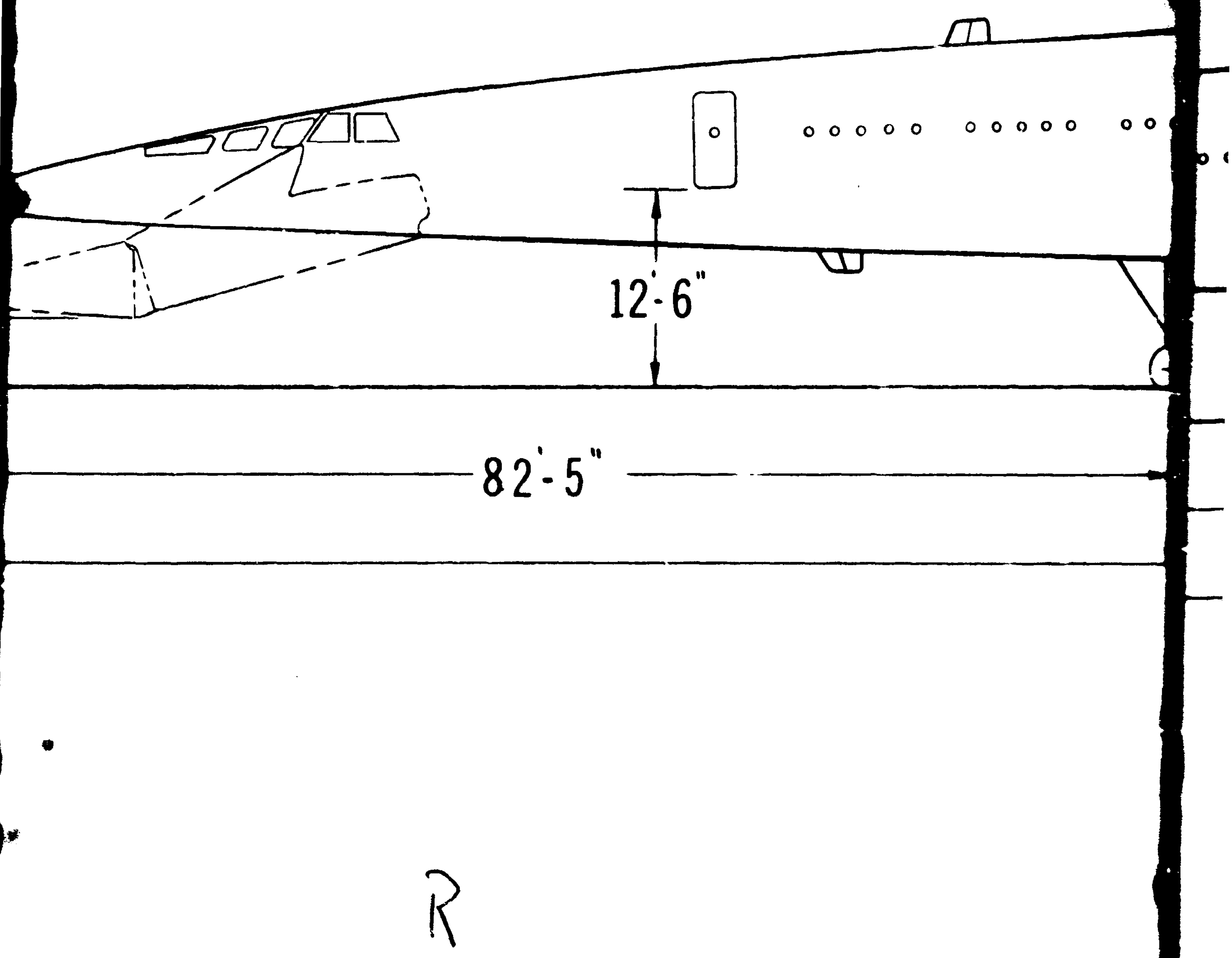
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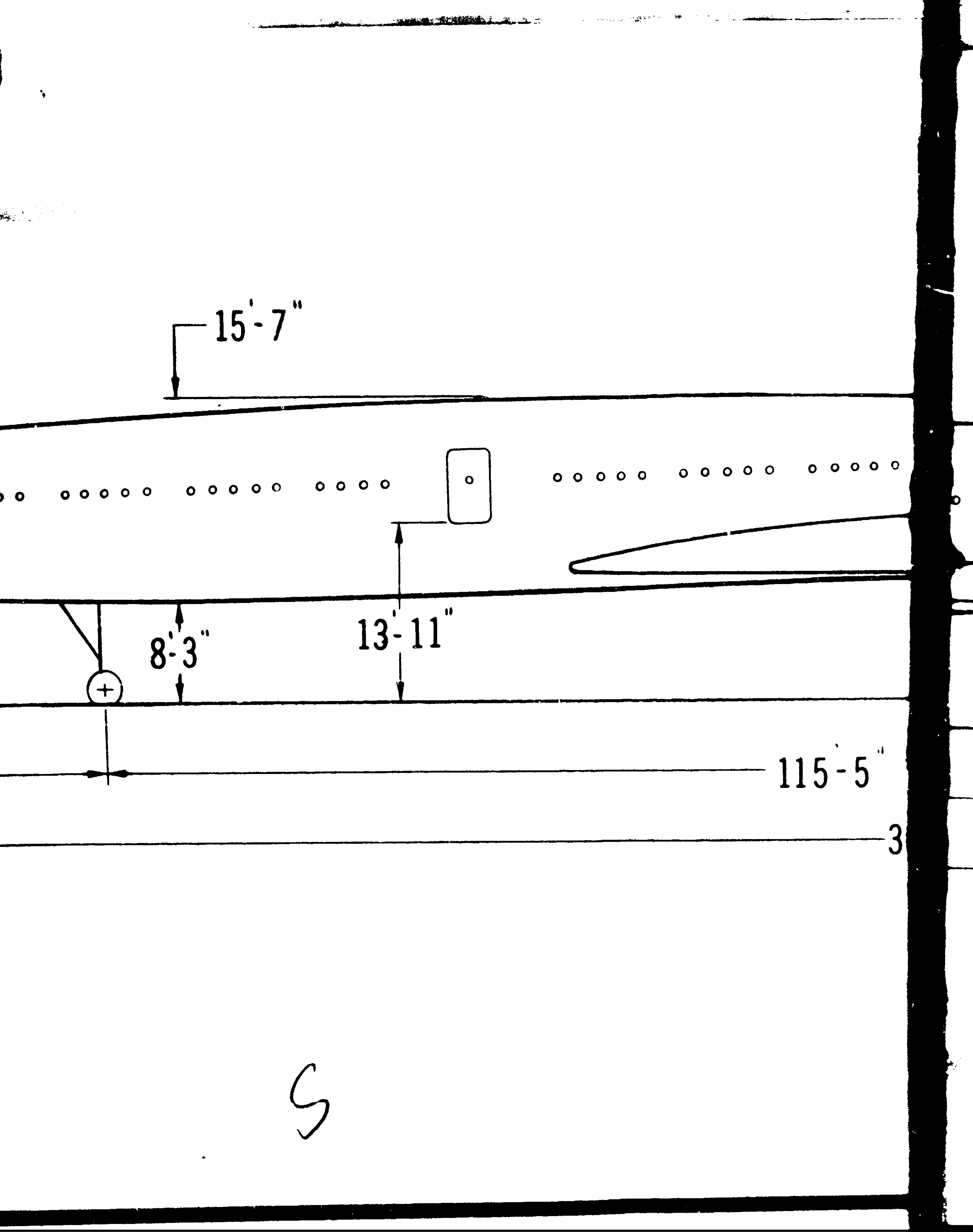
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8'-3"
13'-11"
115'-5"
3
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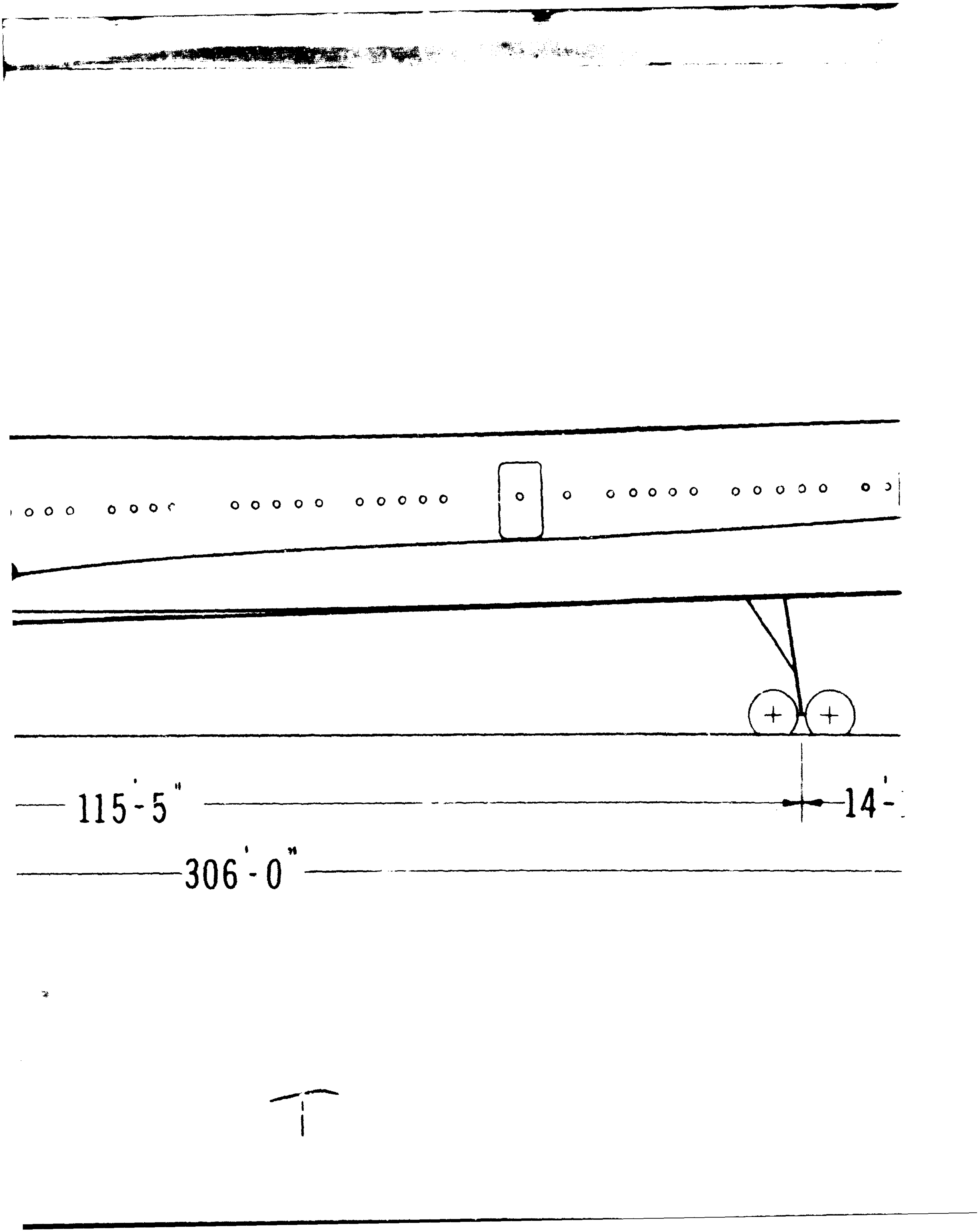

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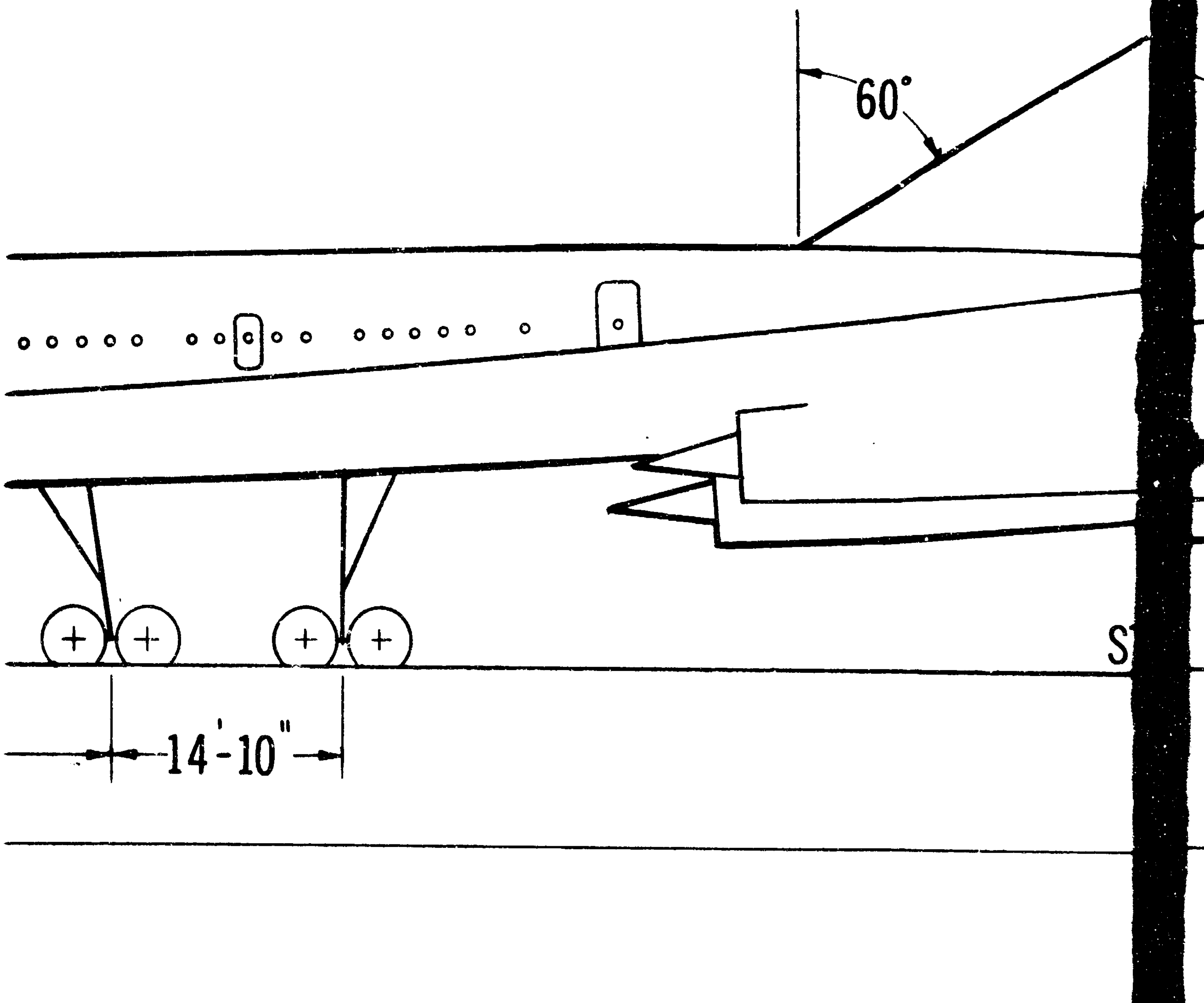
14'-
306'-0"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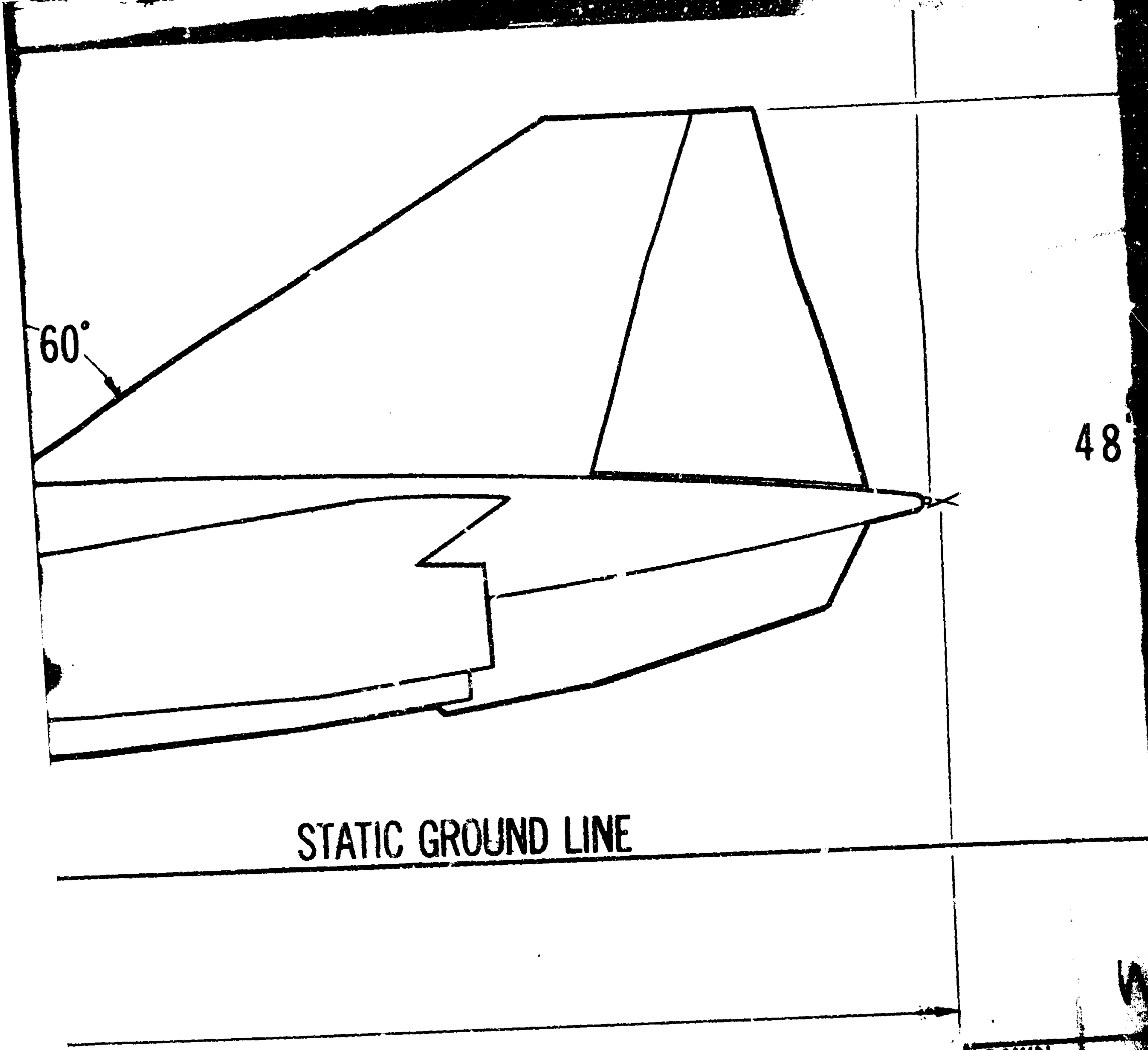

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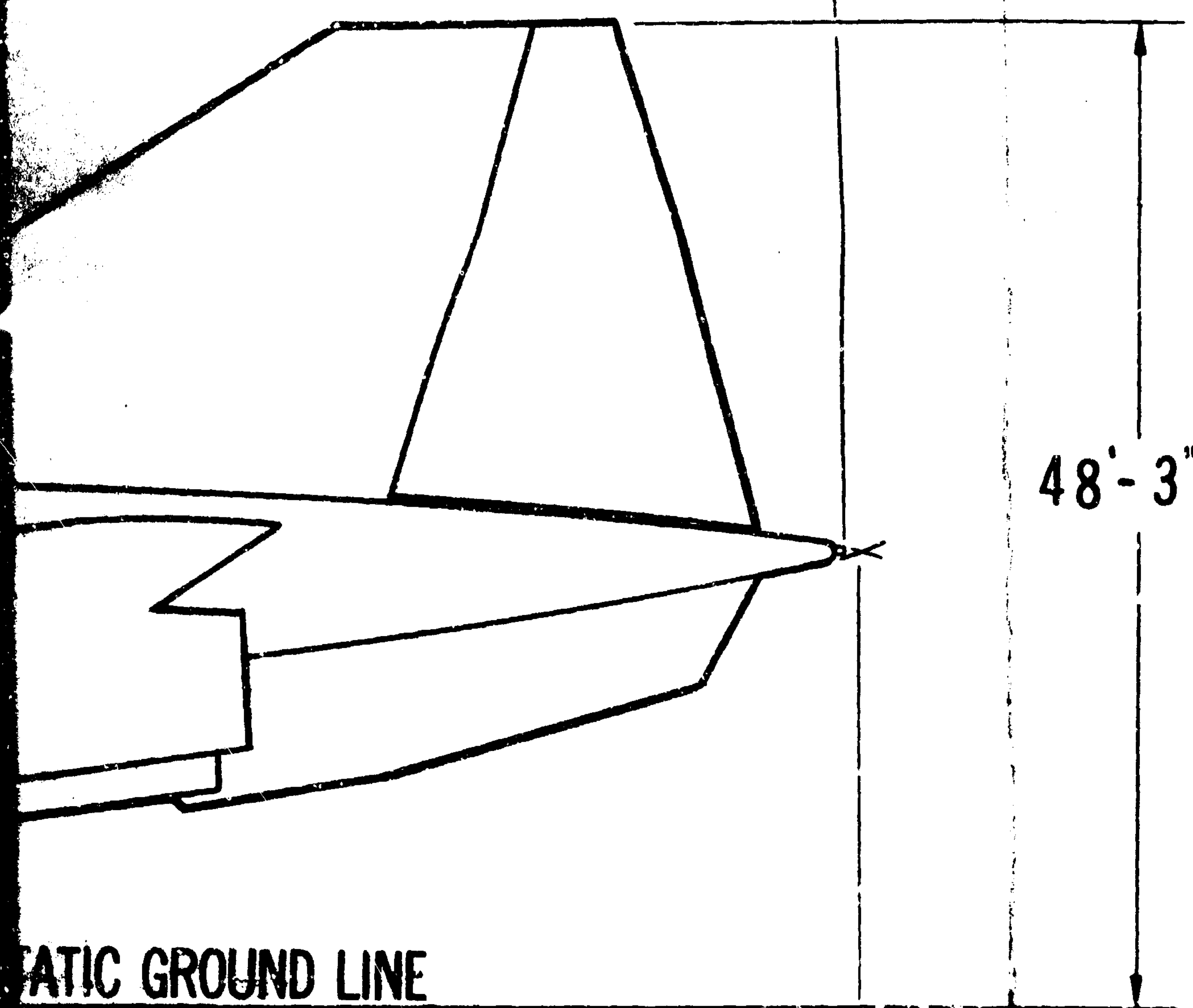

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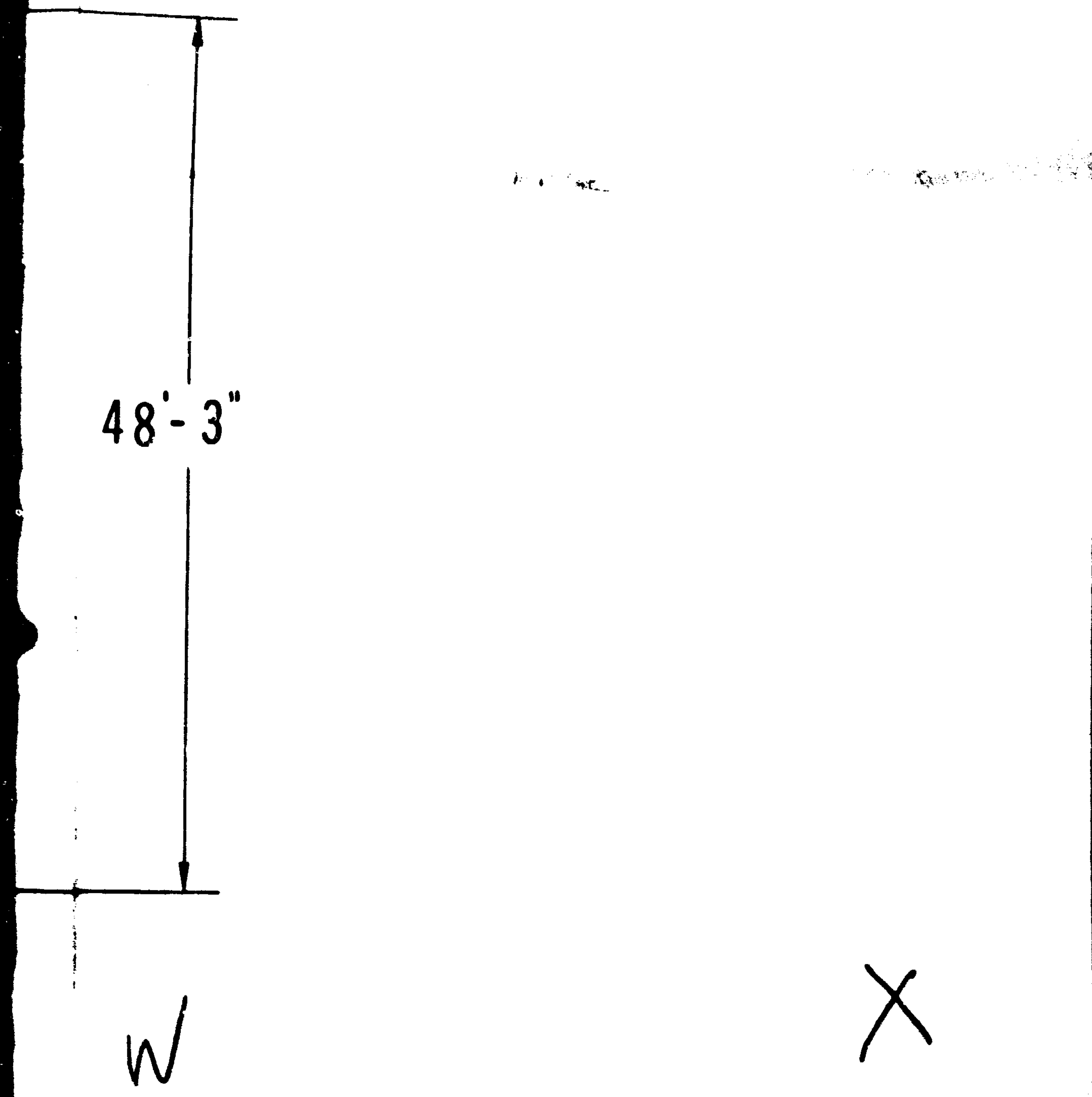

THE BOEING COMPANY
AIRPLANE DIVISION RENTON, WASHINGTON

GENERAL ARRANGEMENT
MODEL B-2707(GE)

CODE IDENT NO. 81205 | SIZE J | 65A10243

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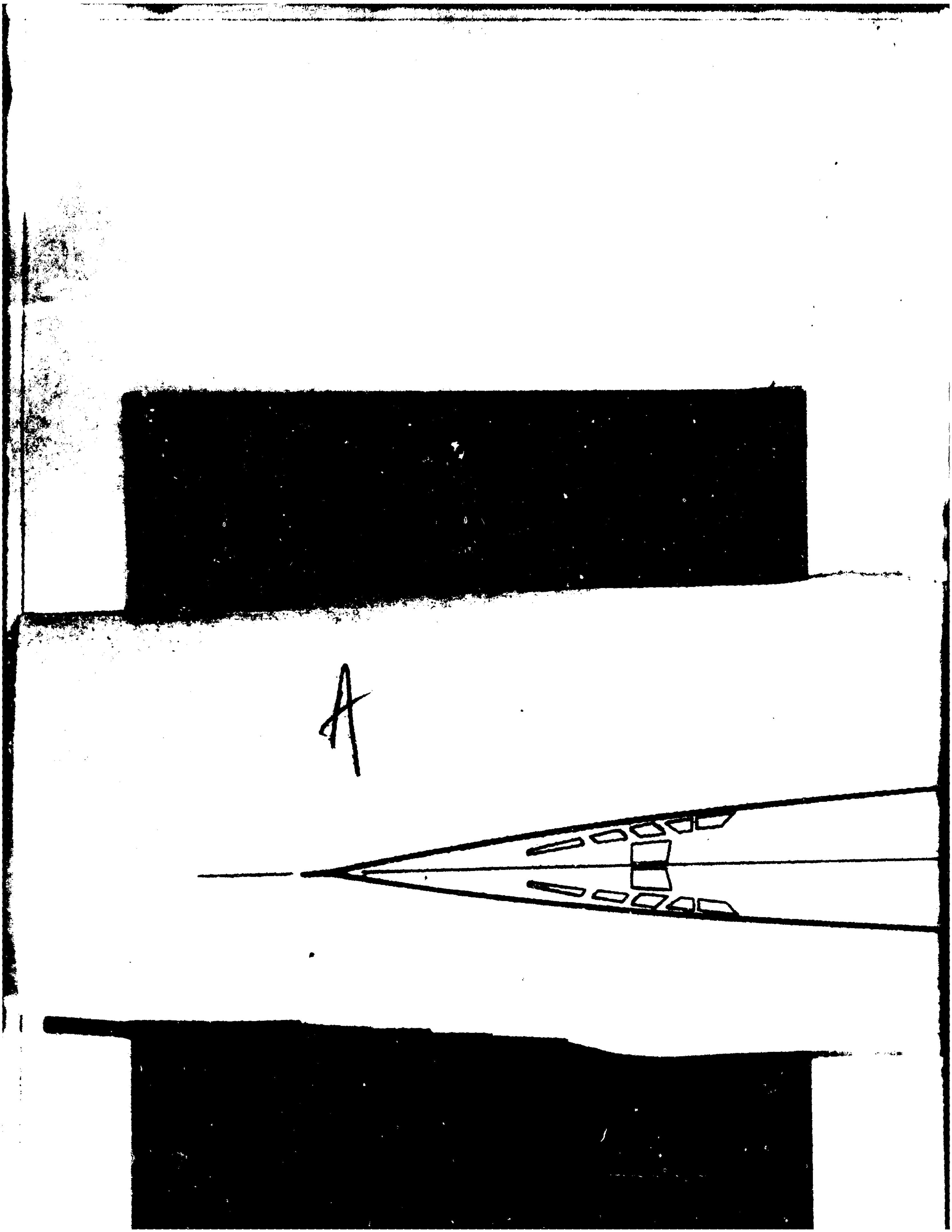
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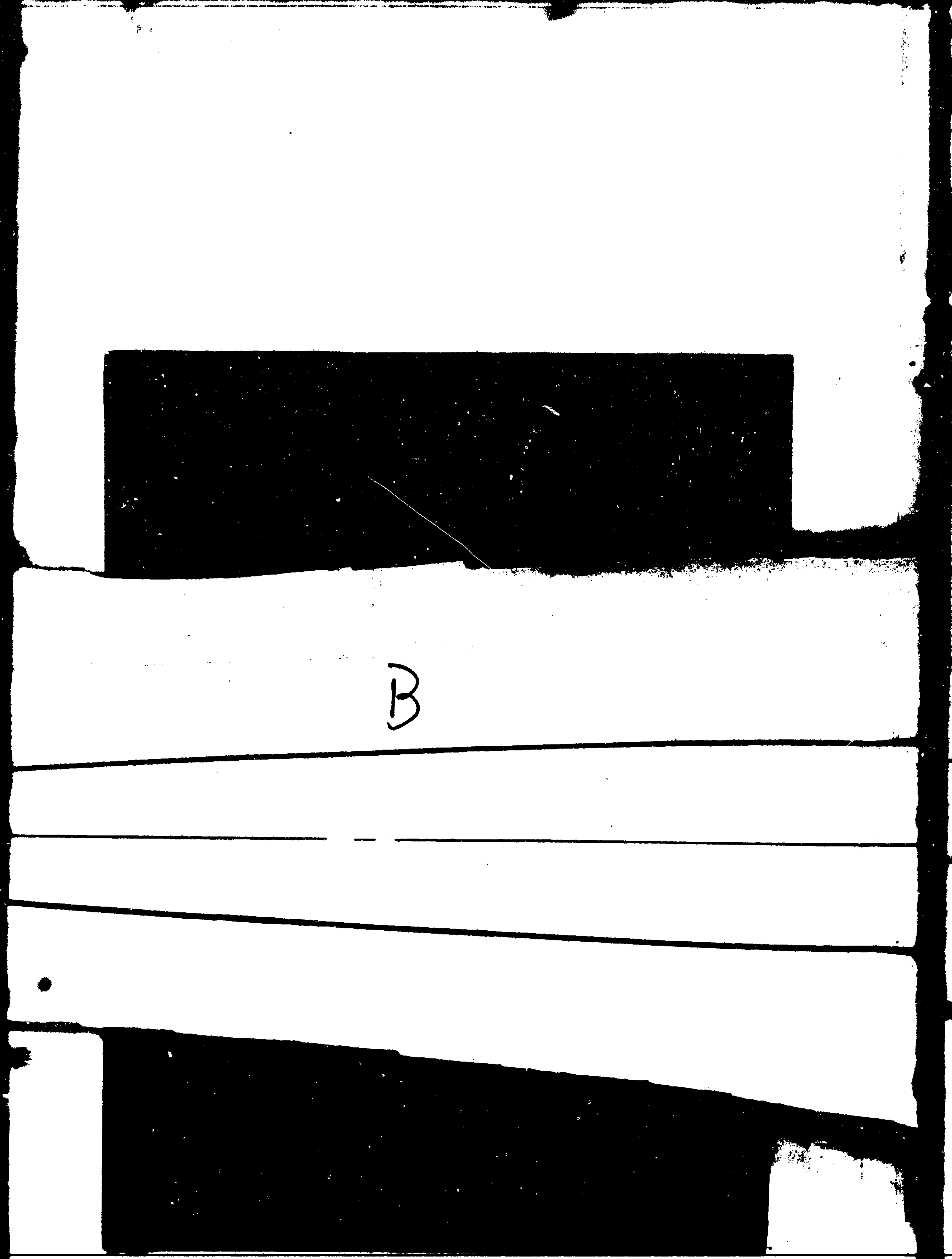
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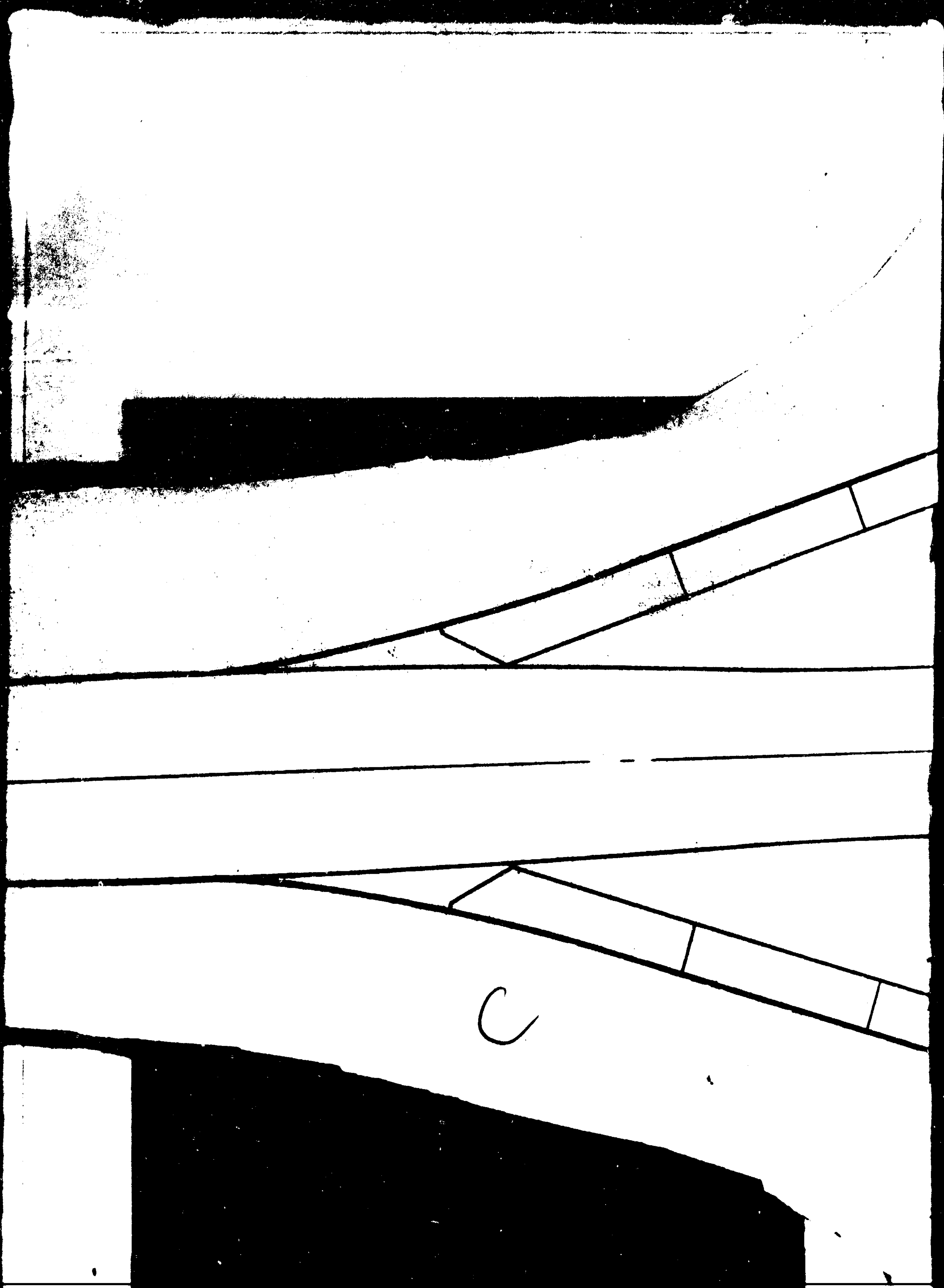
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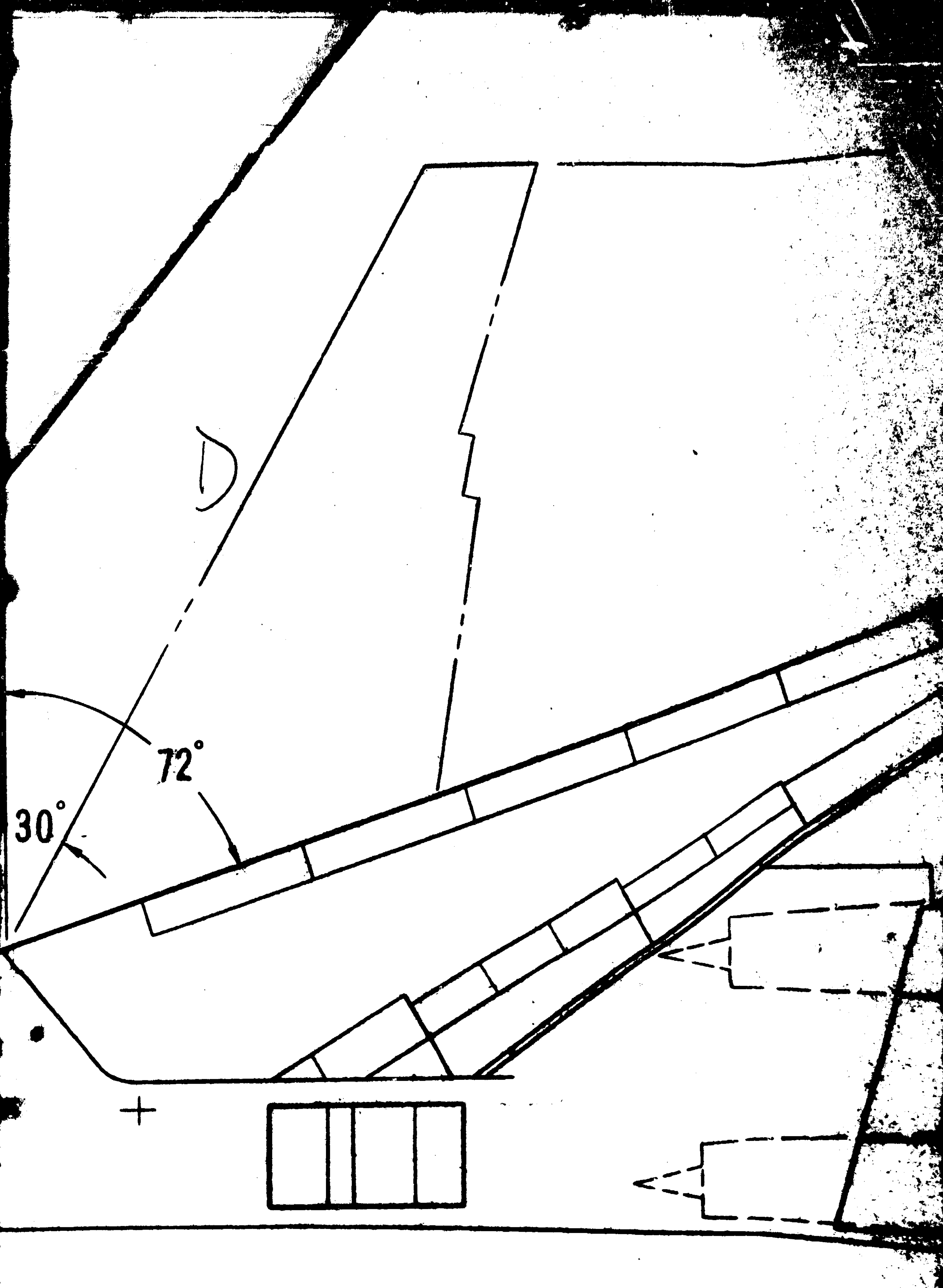

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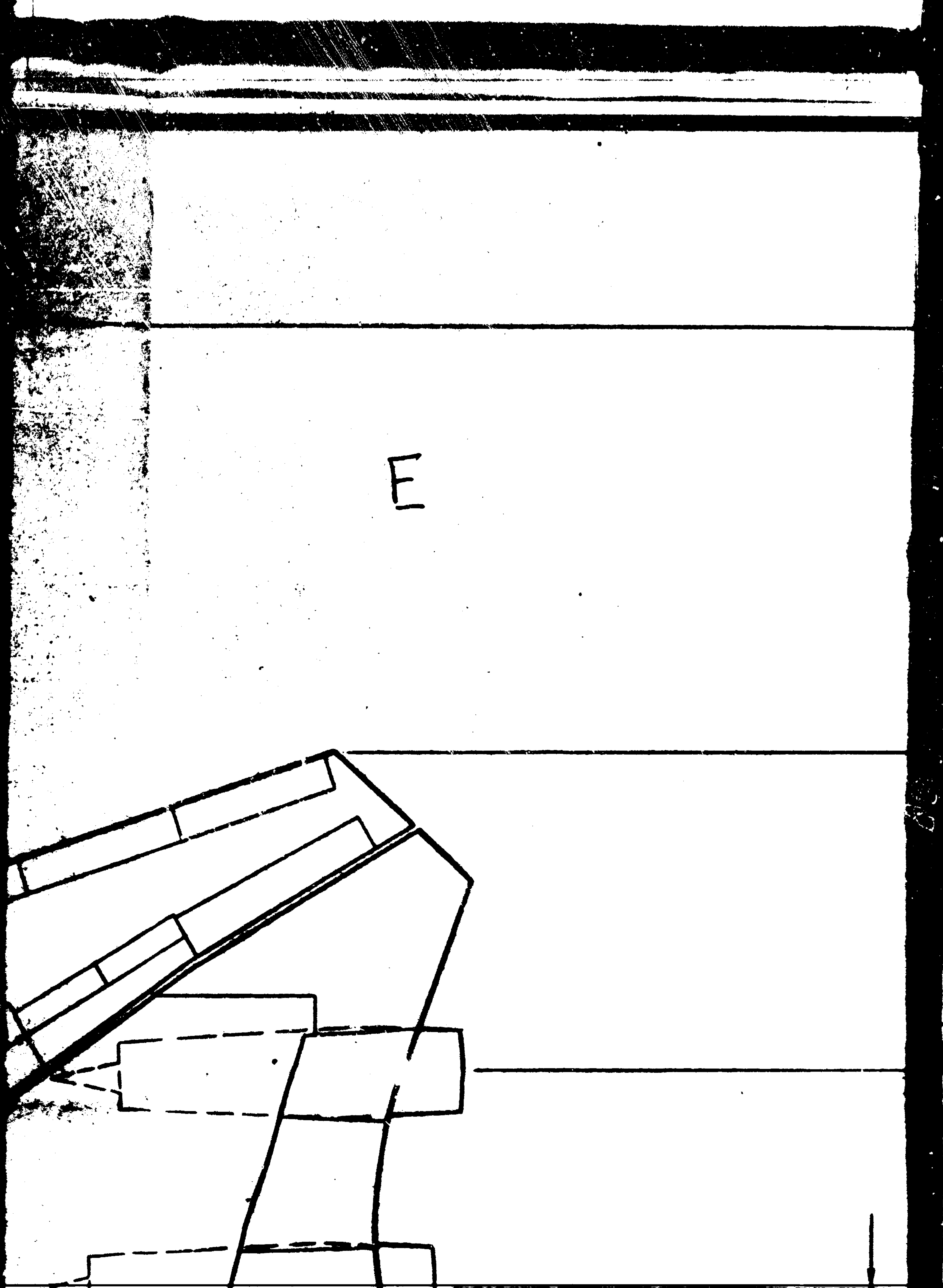
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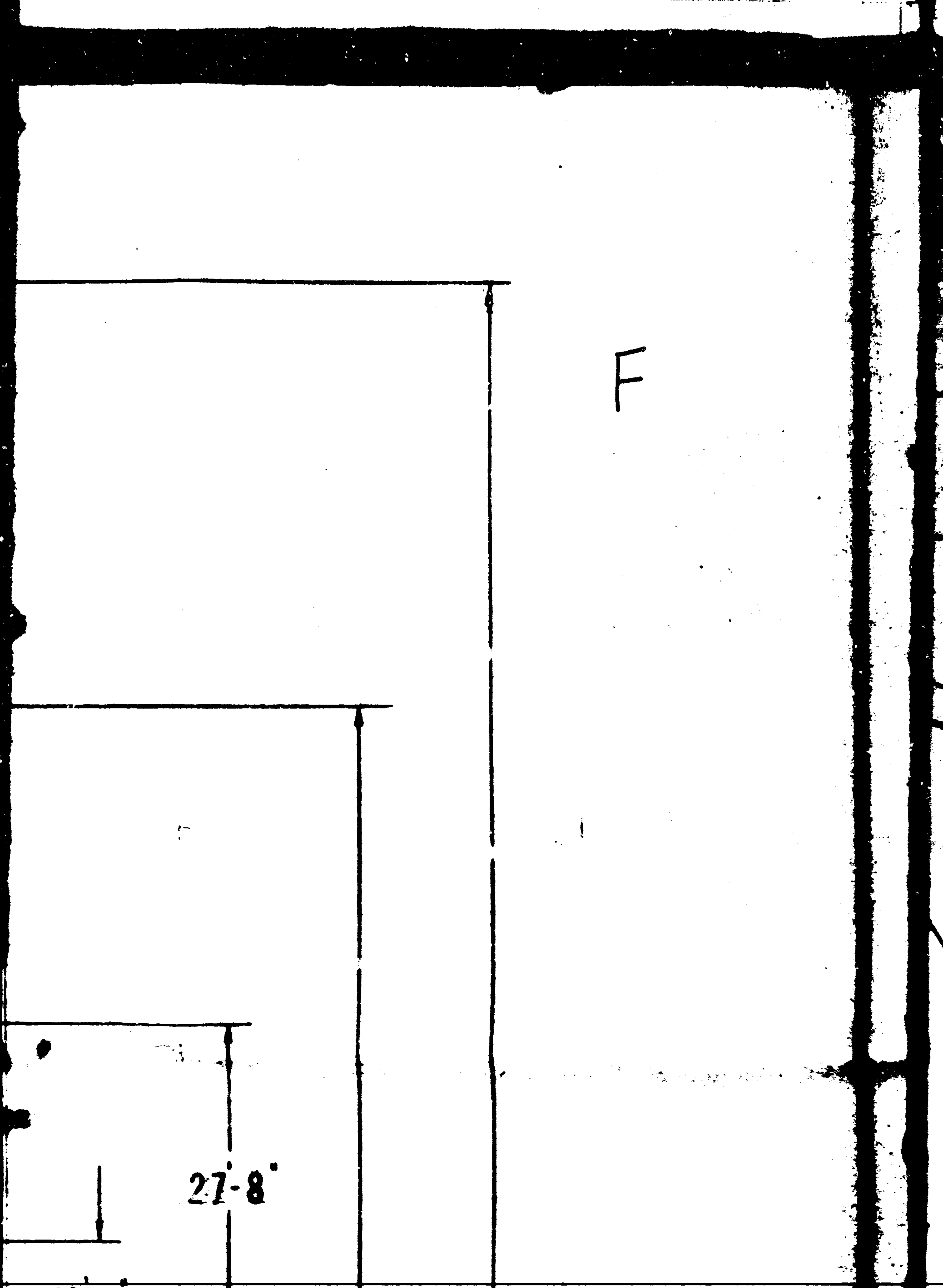
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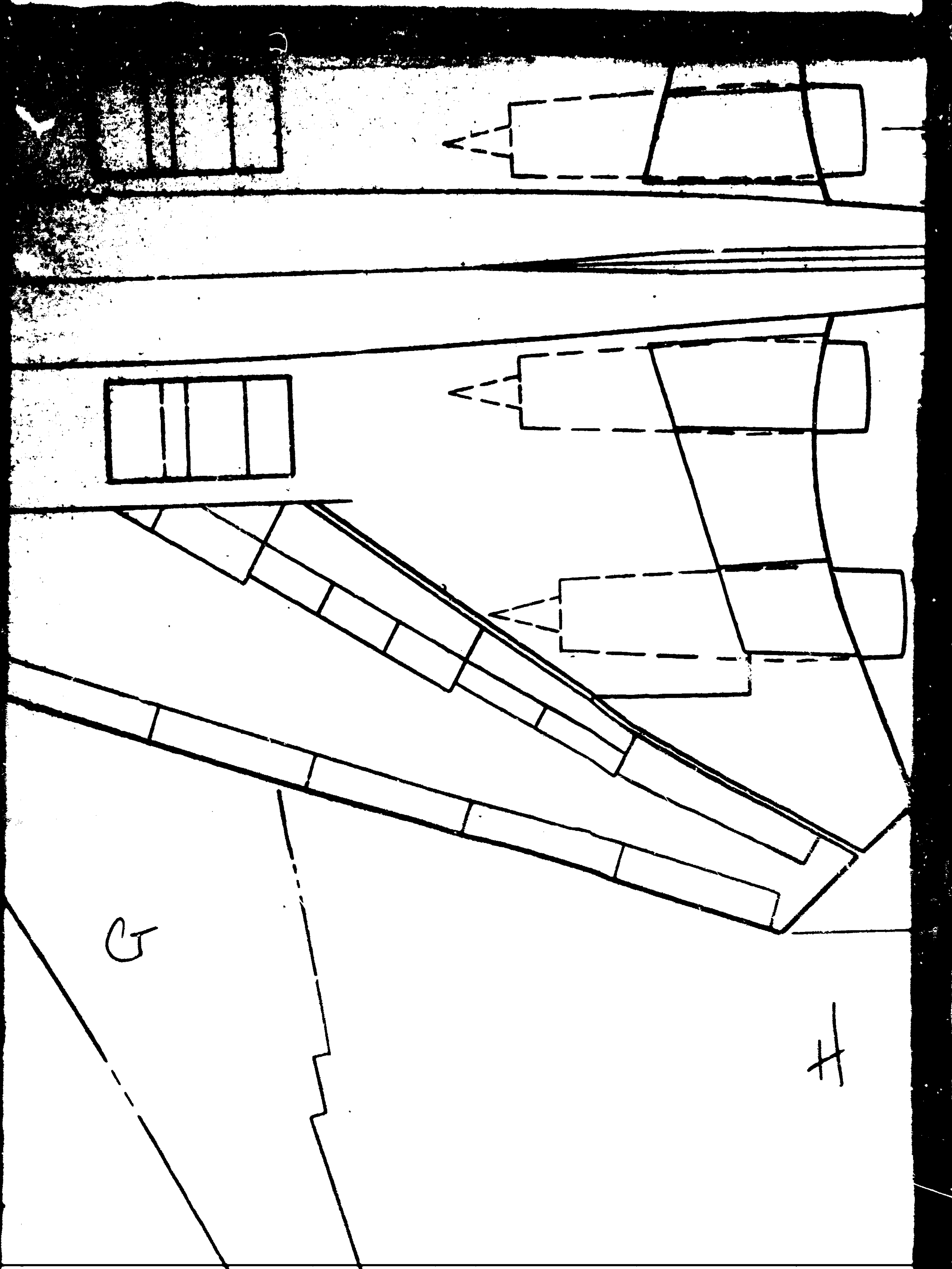
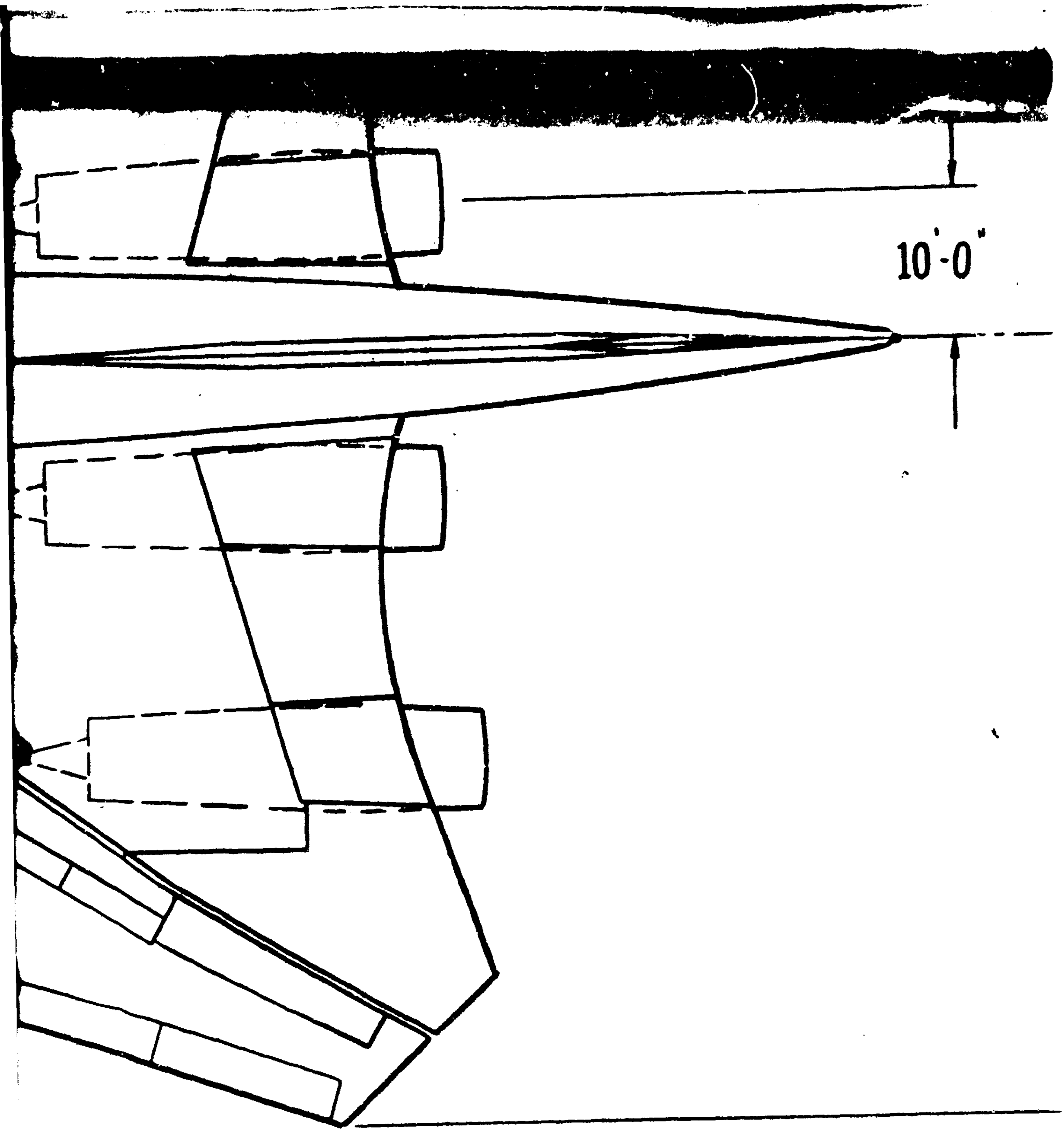
27'-8"


G
H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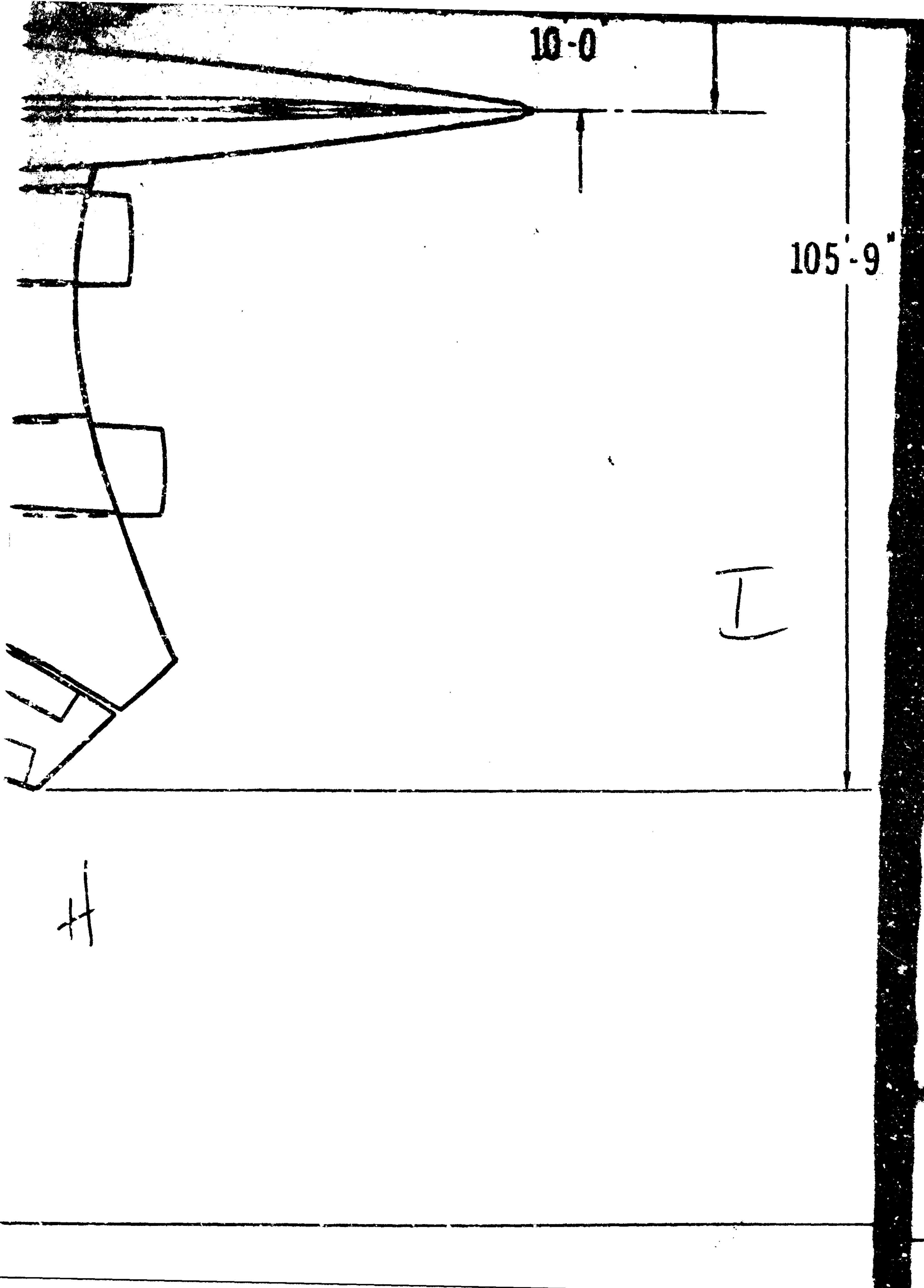
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I
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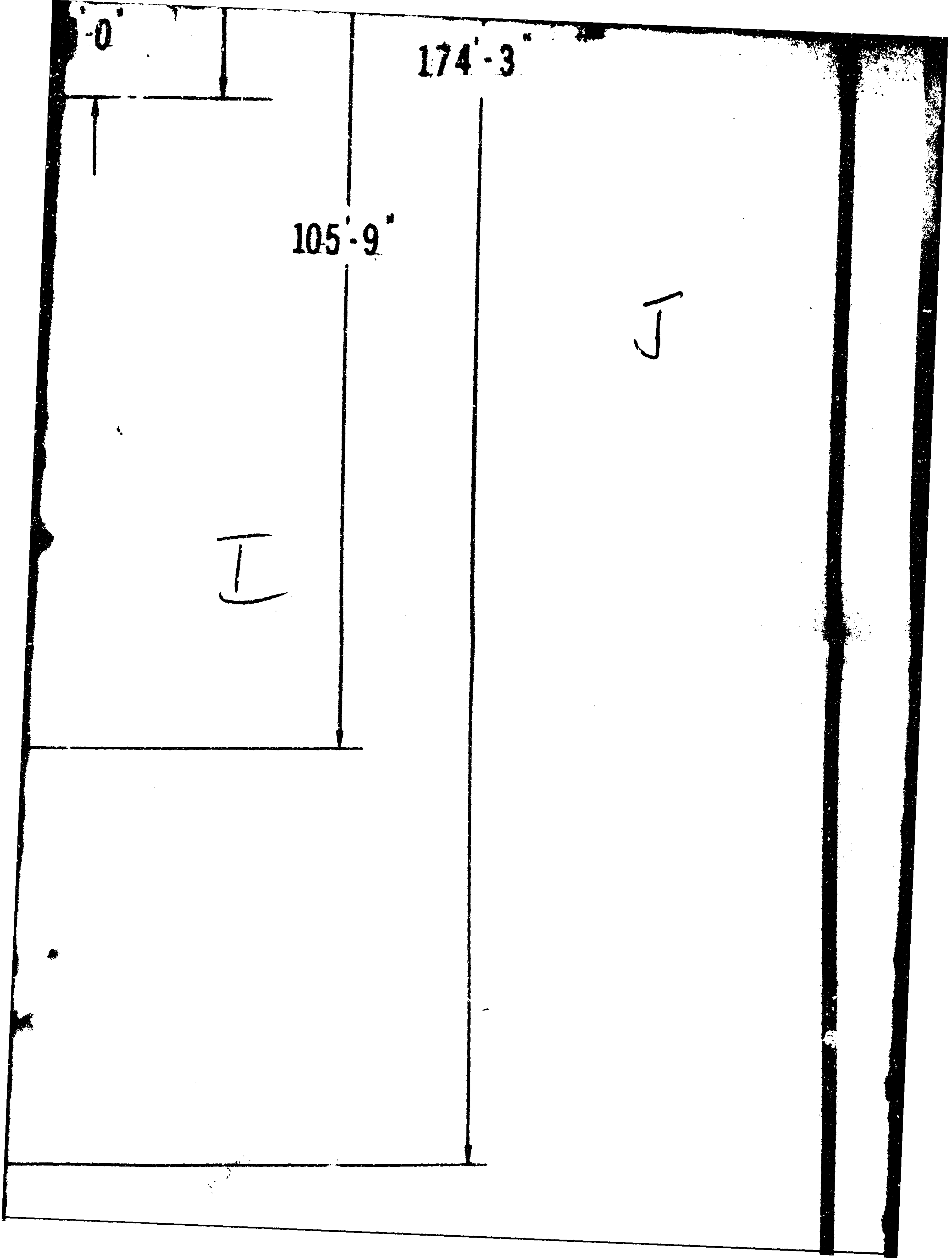

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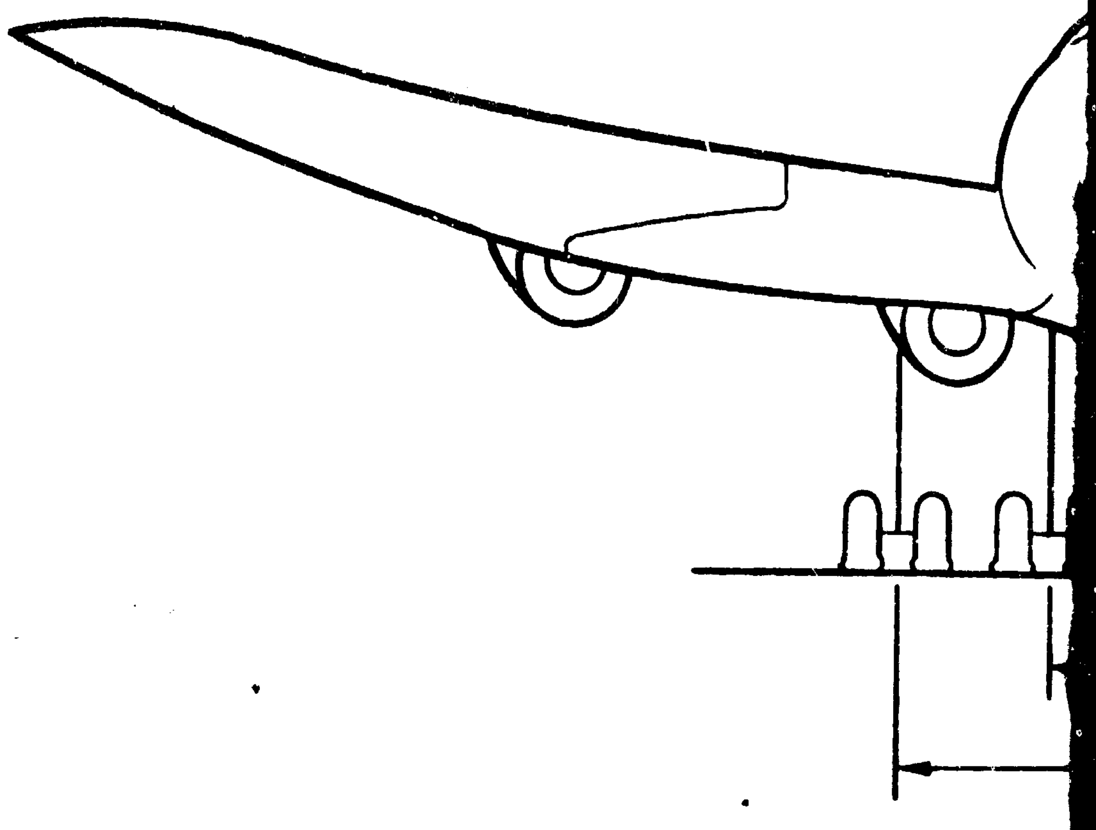
105'-9"
J
I



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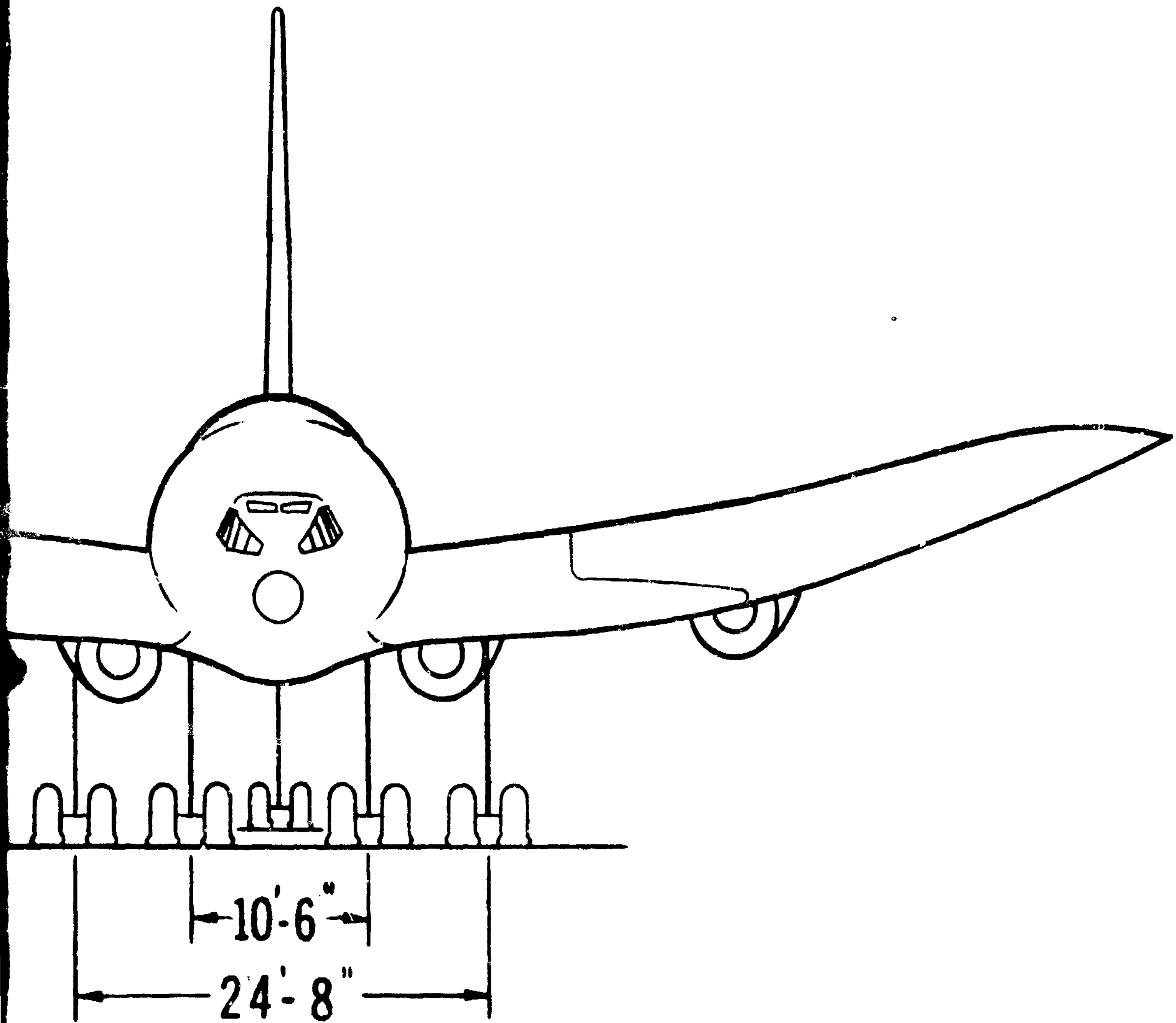

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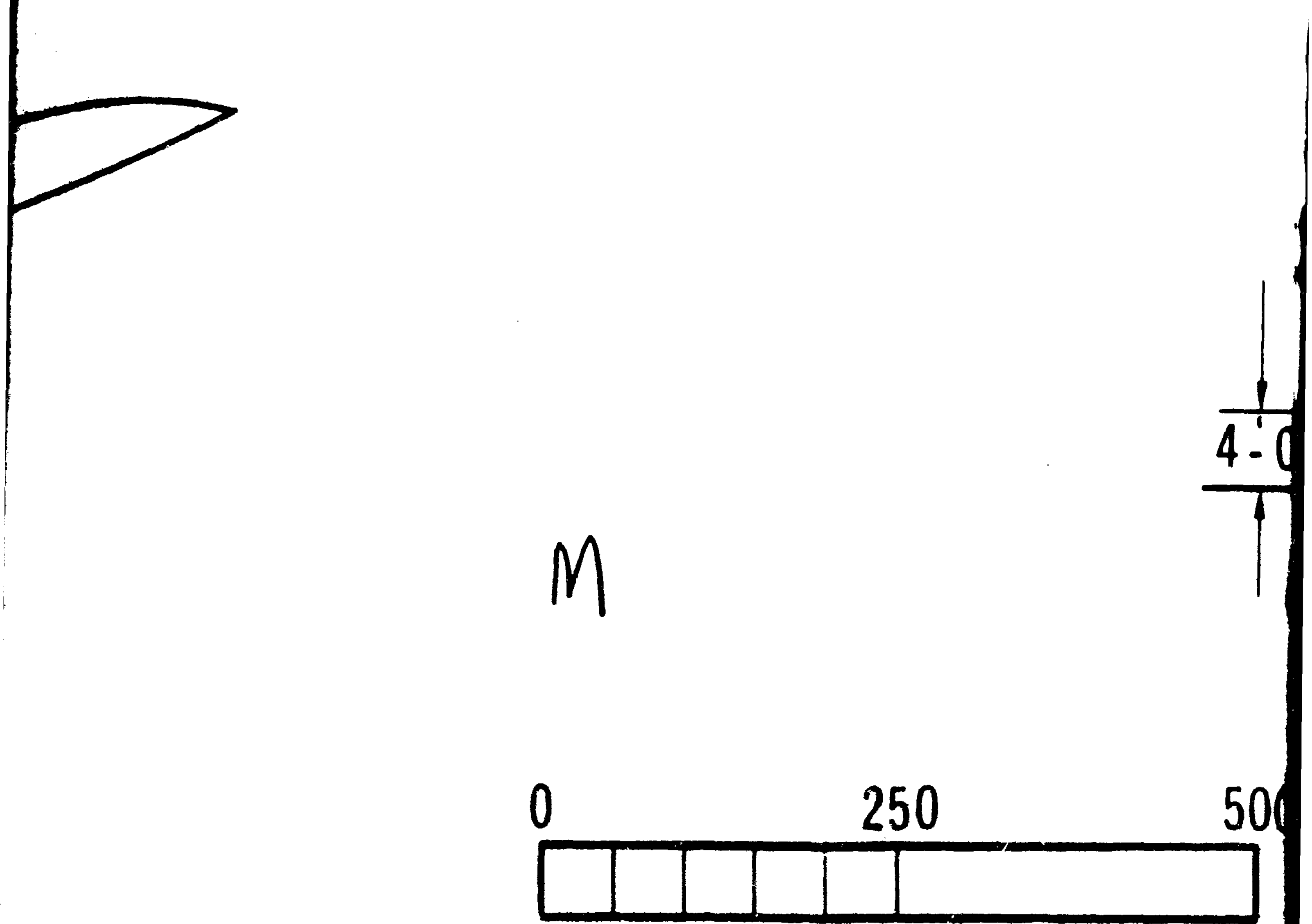
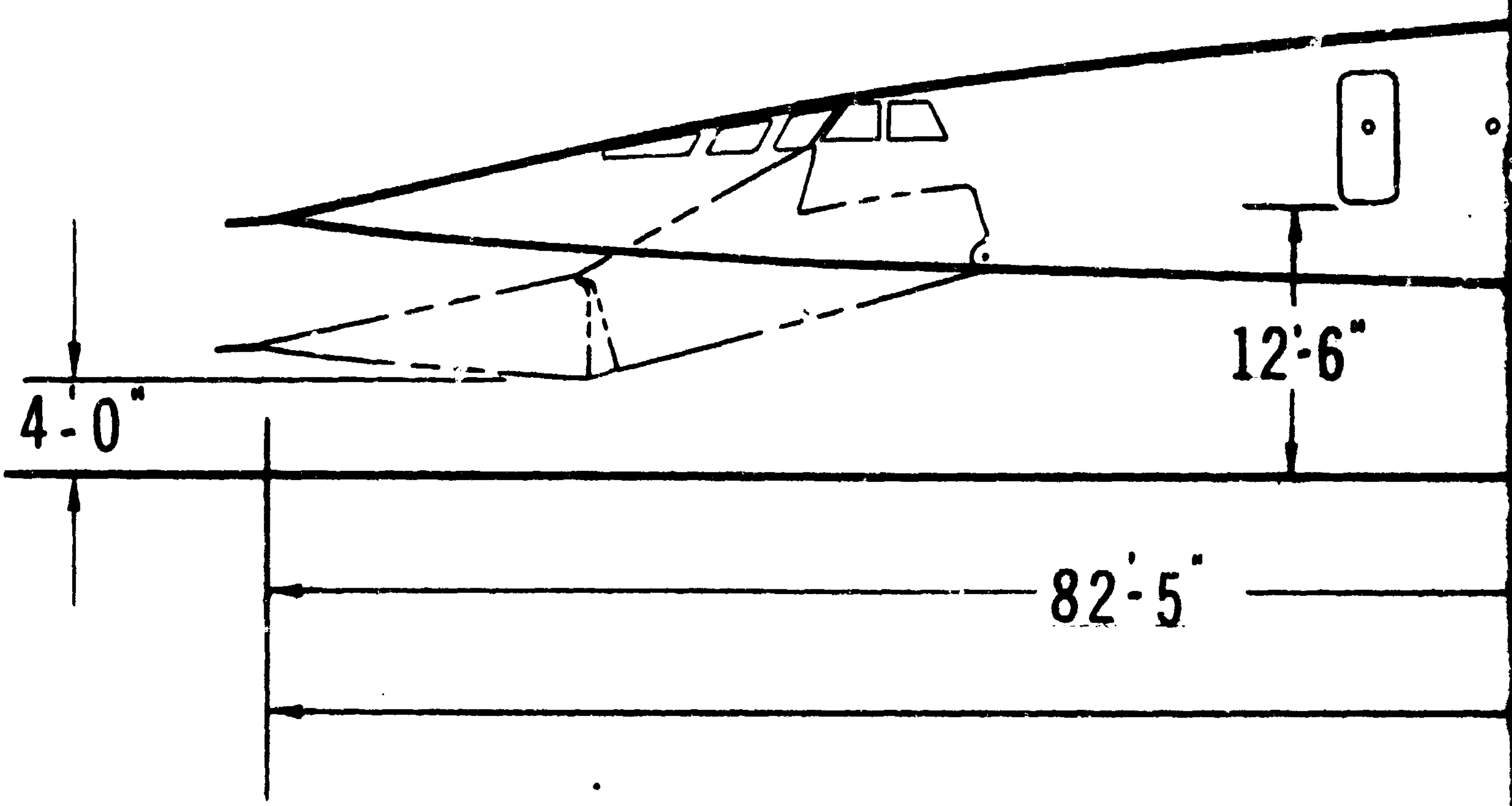


SCALE (INCHES)



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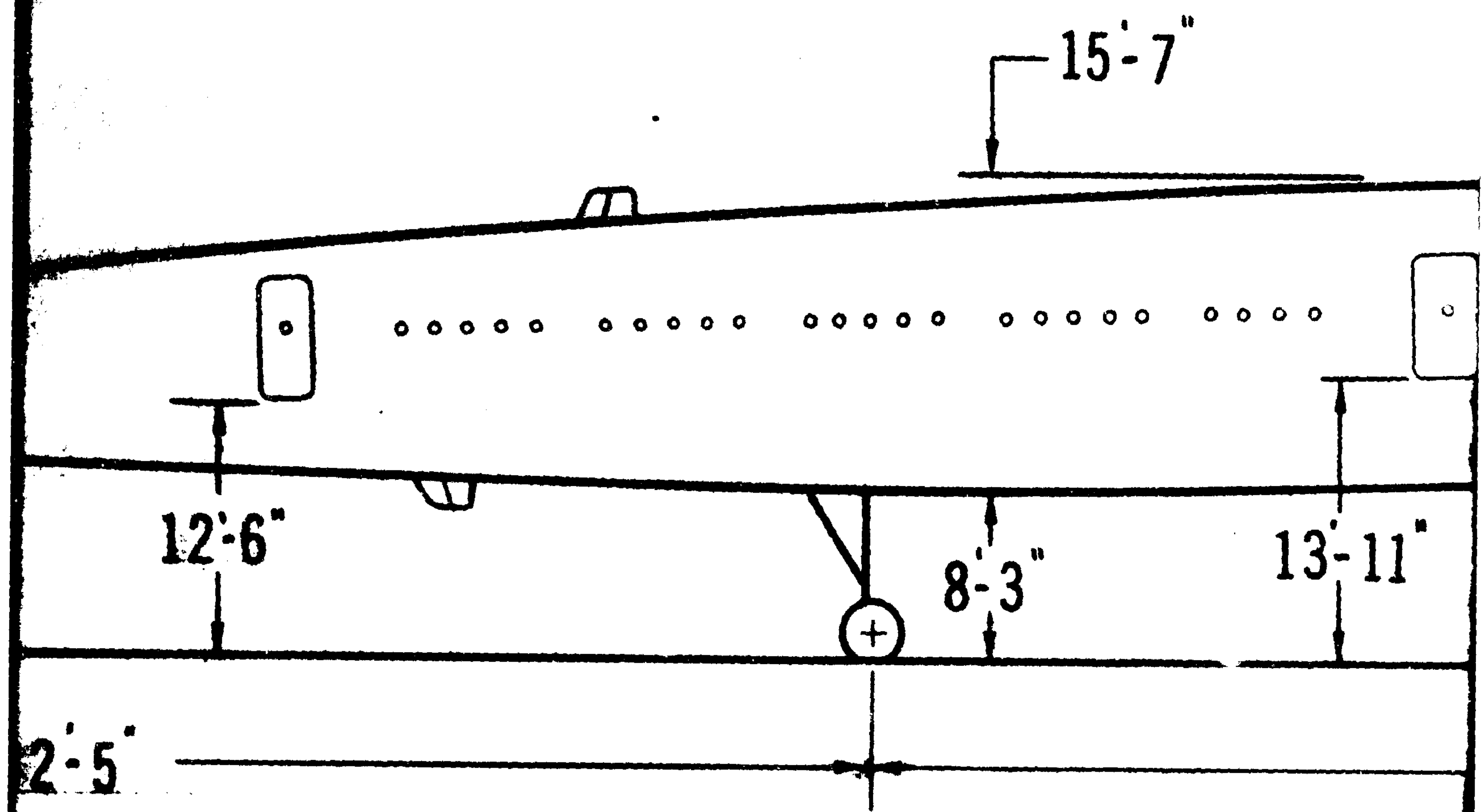

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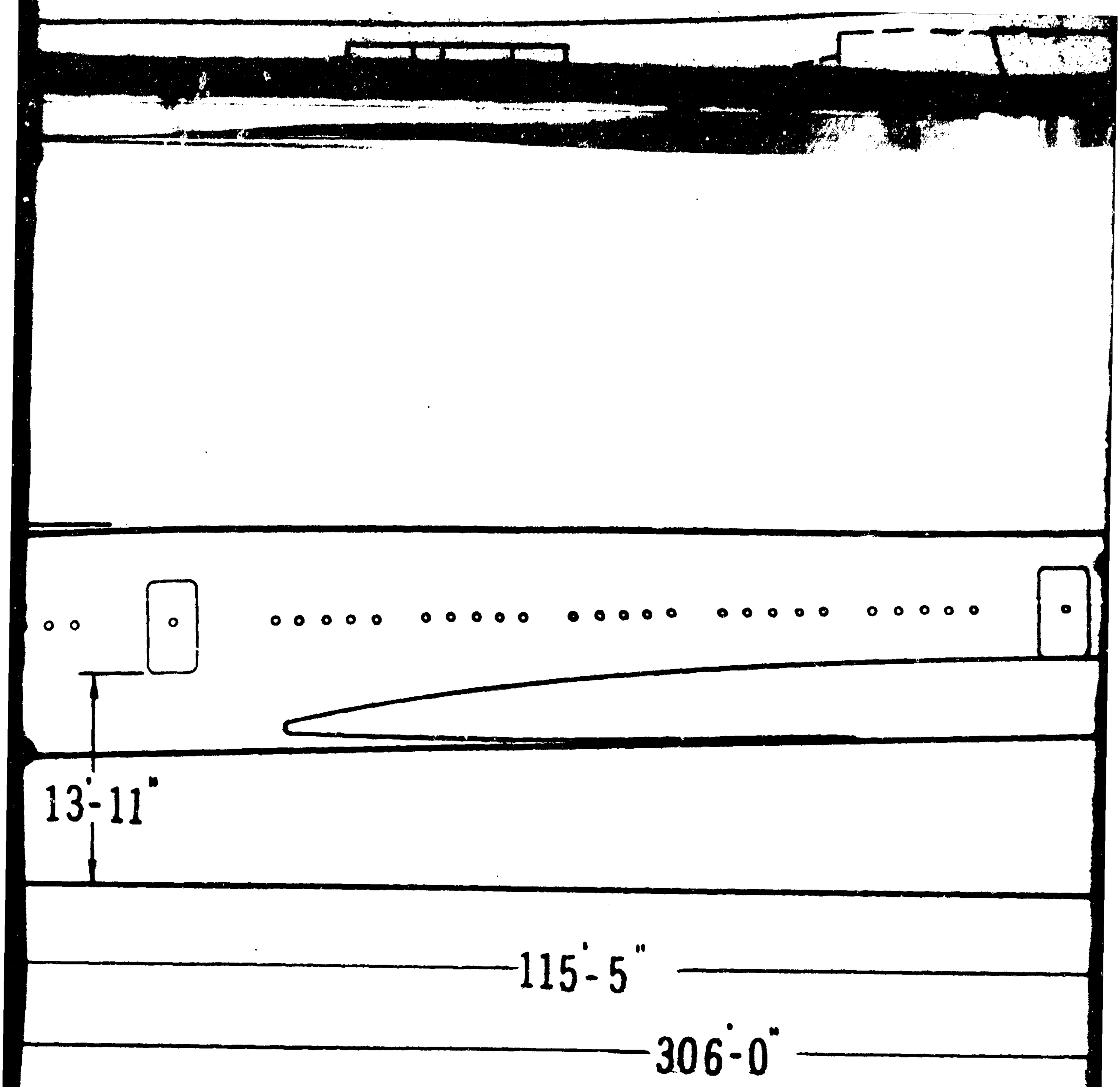

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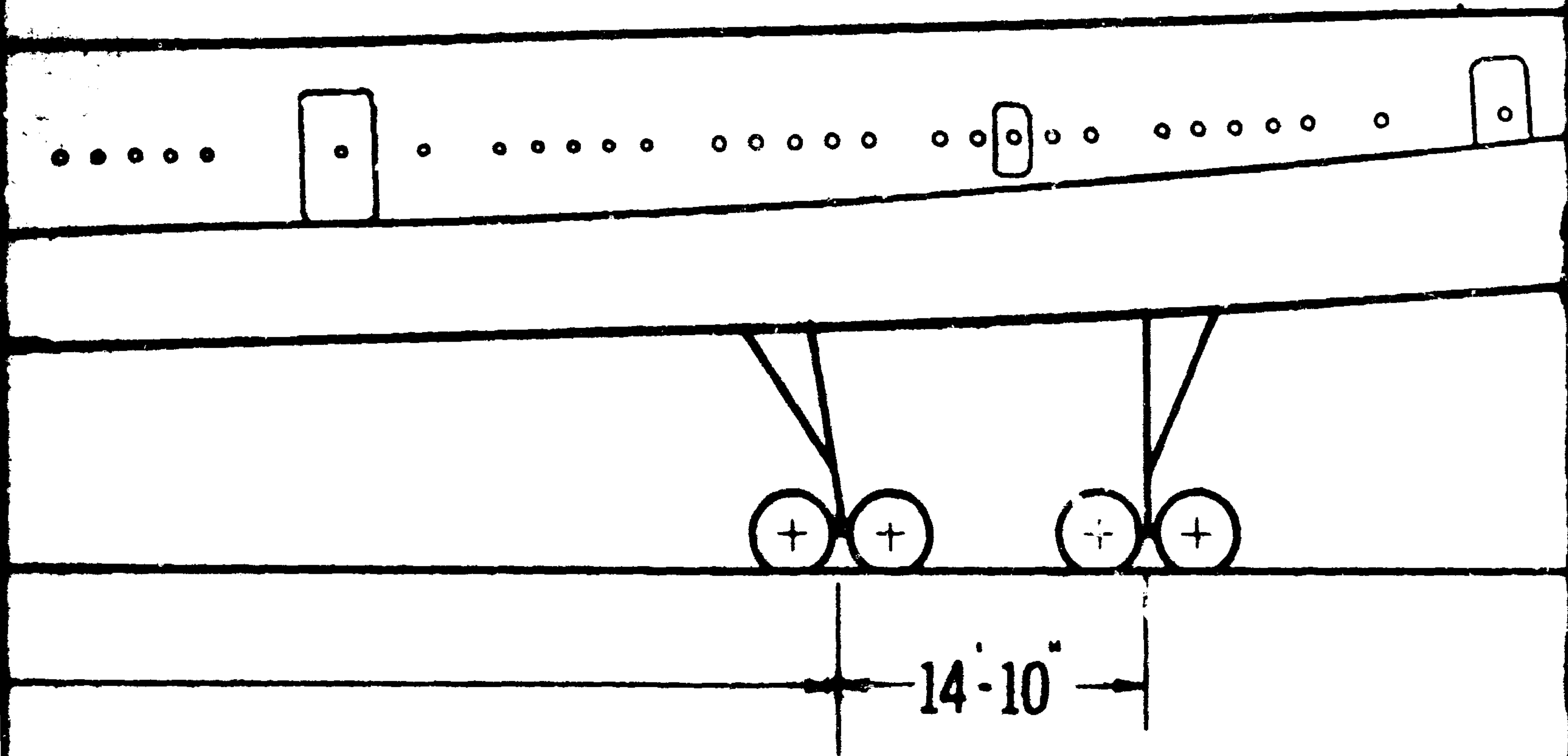

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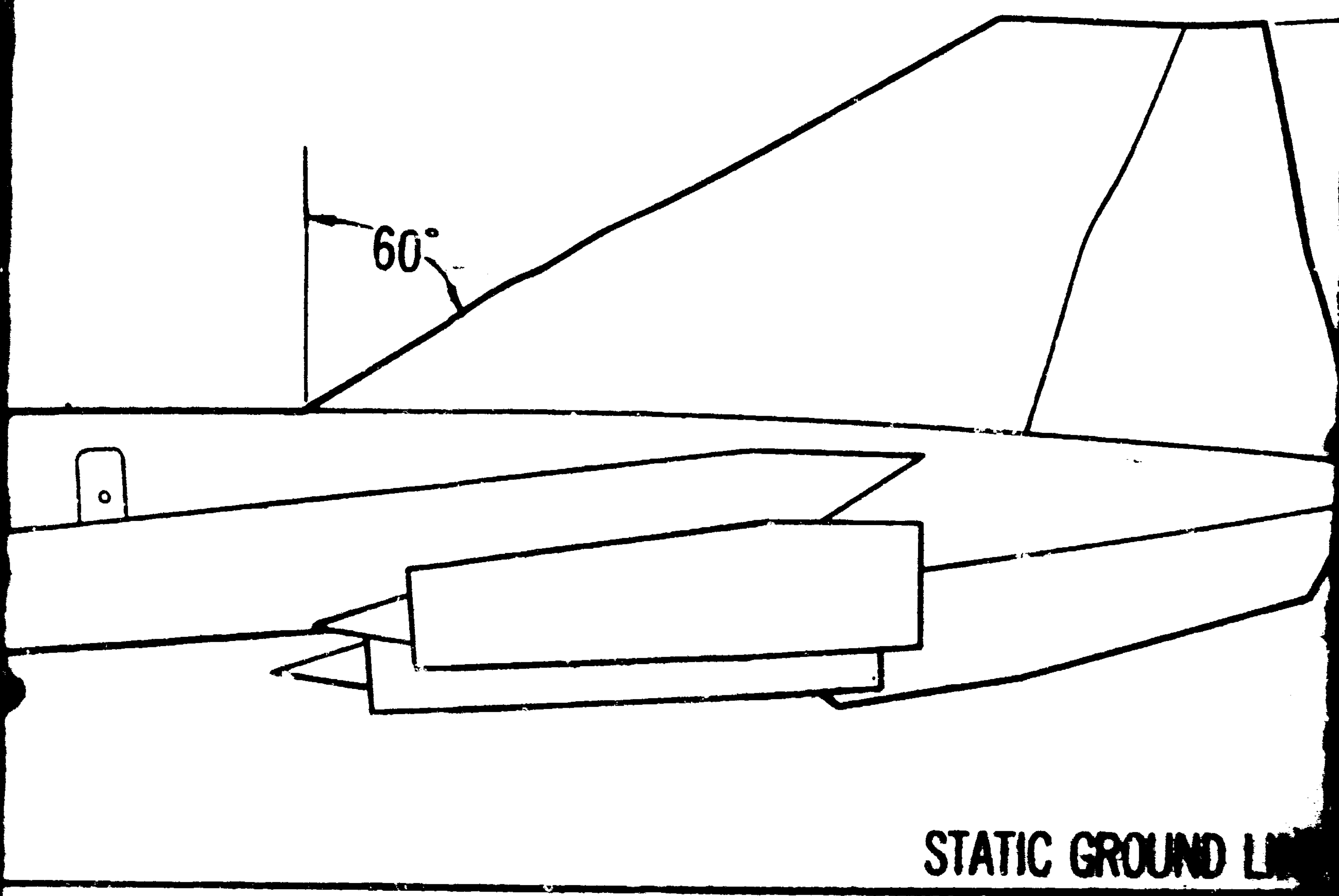

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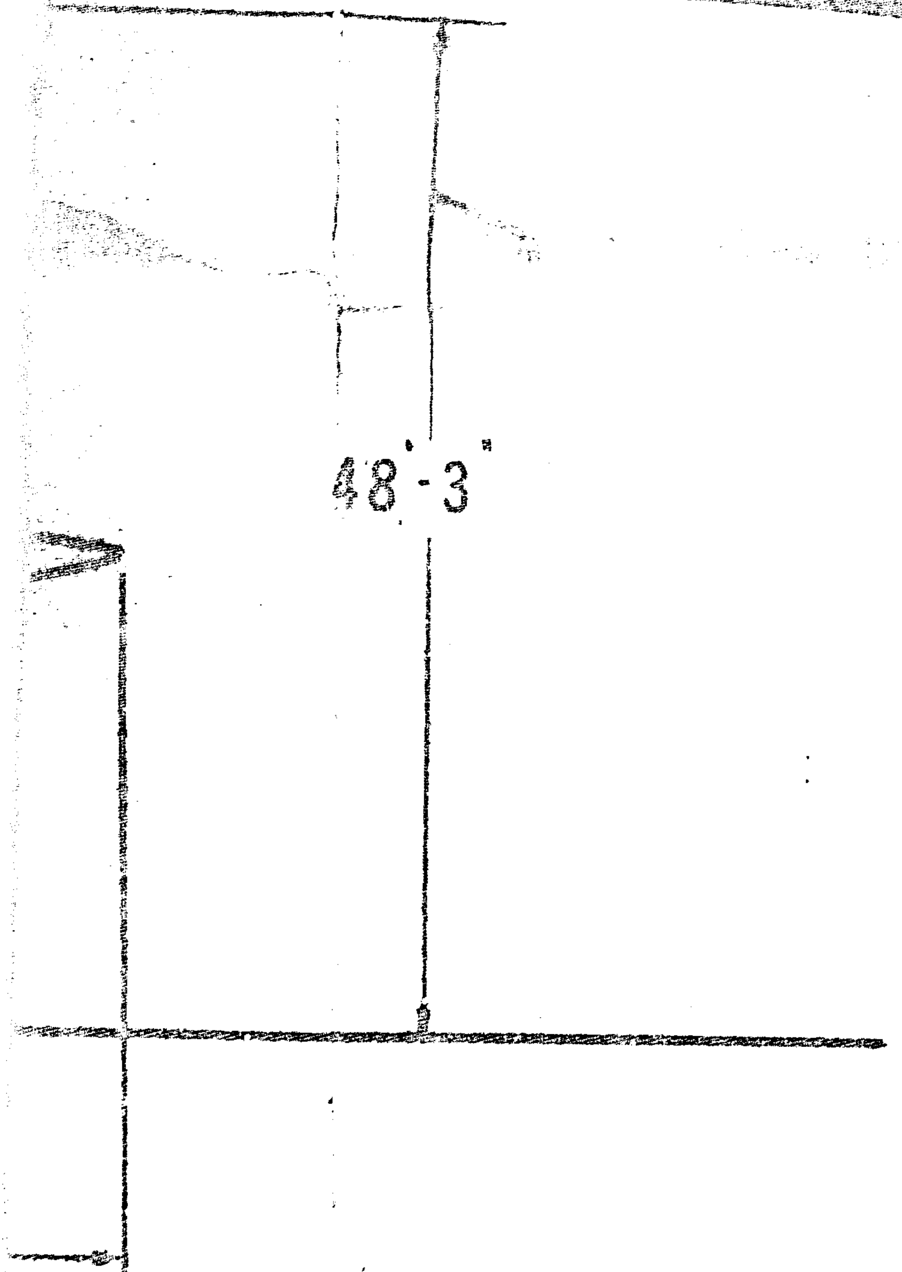

S

DRAWN A. POLO	DATE	THE BOEING COMPANY AIRPLANE DIVISION RENTON, WASHINGTON
CHECKED		GENERAL ARRANGEMENT MODEL B-2707(P&WA)
CODE IDENT NO.	SIZE J	65A10242
	AF	SH

B